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Review of Canadian Municipal Urban Drainage Policies and Practices

Research Report No. 82

ch Program for the Abatement of Municipal Pollution
der Provisions of the Canada-Ontario Agreement
on Great Lakes Water Quality

CANADA-ONTARIO AGREEMENT

RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house project by both Environment Canada and the Ontario Ministry of Environment, and contracts with municipalities, research institutions and industrial organizations.

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REVIEW OF CANADIAN MUNICIPAL
URBAN DRAINAGE POLICIES AND PRACTICES

by

Gore and Storrie Limited
Consulting Engineers
Toronto, Ontario

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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ABSTRACT

Canadian municipal urban drainage practices are summarized, based on information supplied to Environment Canada from provincial and municipal agencies, supplemented by information obtained from a number of consulting engineers across Canada. The summary is presented in three parts:

- Design of new sewer systems
- Abatement of pollution due to combined sewer overflows
- Field studies of sewer systems

Many of the problems associated with the quantity of flow aspect of urbain drainage, such as basement flooding, have long been apparent to most municipal engineers. There is now an increasing awareness by regulatory bodies of the qualitative effects of urban drainage on receiving waters. At the municipal level, attention is being given to the new storm water management techniques for solving quantity and quality problems through storage and treatment of storm water flows. Mathematical simulation models are being used for analyses of municipal urban drainage systems. There is still much work to be done, however, in collecting background data and refining and calibrating the computer programs in order to obtain the closest relationships with actual conditions.

Research and development projects on urban drainage problems are being sponsored at the federal and provincial levels and are providing additional knowledge pertinent to Canadian conditions, and considerable impetus to the application of storm water management techniques all across Canada.

RÉSUMÉ

On résume les méthodes municipales de drainage urbain au Canada à partir de renseignements qu'ont fournis au ministère de l'Environnement du Canada des organismes provinciaux et municipaux et des ingénieurs-conseils. Le sommaire se divise en trois parties:

La conception de nouveaux réseaux d'égout;
La réduction de la pollution due aux
trop-pleins d'égouts combinés et
L'étude sur place des réseaux d'égout.

La plupart des ingénieurs municipaux connaissent depuis longtemps les problèmes multiples liés au débit du drainage urbain comme, par exemple, l'inondation des sous-sols. Les organismes investis d'un pouvoir de réglementation prennent de plus en plus conscience maintenant des effets qualitatifs du drainage urbain sur les eaux réceptrices. Les municipalités s'intéressent aux nouvelles techniques d'aménagement des eaux pluviales pour résoudre ces problèmes qualitatifs et quantitatifs par rétention et traitement des eaux pluviales. On fait appel à des modèles mathématiques de simulation pour analyser les réseaux municipaux de drainage urbain. Cependant, il reste encore énormément de travail à accomplir pour recueillir les données de base, perfectionner et étalonner les programmes informatiques si l'on veut vraiment établir d'étroites corrélations avec les conditions réelles.

Actuellement, les gouvernements fédéral et provinciaux, financent des projets de recherche et de développement en ce qui concerne le drainage urbain, améliorent ainsi les connaissances en ce domaine au Canada et stimulent considérablement l'application de techniques d'aménagement des eaux pluviales au pays.

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SUMMARY

As a part of the research and development program of the Urban Drainage Subcommittee of the Canada-Ontario Agreement on Great Lakes Water Quality, a study was made of the current policies and practices across Canada with respect to urban storm water drainage. The information was assembled from a questionnaire sent to their regional offices by the Environmental Protection Service of Environment Canada. Three categories of the major practices in urban drainage were considered by the questionnaire, namely:

I - Design of New Sewer Systems

II - Abatement of Pollution Due to Combined Sewer Overflows

III - Field Studies of Sewer Systems

There did not appear to be any great discrepancies in the policies and practices used for urban drainage in the various provinces across Canada. There were minor variations in approach due to local conditions. At the present time, it appears that we are in the midst of a transition of new philosophies in urban drainage and storm water management and this has received more attention in some provinces than in others. This is probably partly due to geographical location and partly to economic growth considerations.

Nevertheless, provincial regulatory bodies are generally becoming more and more aware of the problems of urban drainage and concerned with the quality effects on receiving waters. Ontario, for example, has taken a definite step towards storm water treatment in requiring quality control of urban surface runoff into the Rideau River in the Ottawa area.

At the municipal level, many of the larger and older cities and towns in Canada were concerned with both quality and quantity problems of urban drainage, and most particularly where these problems arise from combined sewer overflows. Vancouver and Toronto have engaged consultants to analyze their problems. Many municipalities were also looking into the new methods and techniques for management

of all aspects of urban drainage runoff, including analysis by one or more of the mathematical simulation models that are now available for this purpose.

Through the Urban Drainage Subcommittee of the Canada-Ontario Agreement on Great Lakes Water Quality, established in 1971 in response to the recommendation of the International Joint Commission, a research and development program has been conducted on urban drainage management. The program has three main objectives:

- Identify urban drainage problems.
- Develop a capability to solve these problems.
- Develop a strategy to implement these solutions.

About 40 research projects have been undertaken by the Subcommittee and considerable progress has been made with respect to the first two of the above objectives. Work is now proceeding with respect to the third objective. At an Urban Drainage Conference held in Toronto, Ontario, March 1977, the Subcommittee presented a draft of a "Manual of Practice on Urban Drainage" for review and comment by those persons interested and working in this field. It is an attempt to set out current thinking and improved practices in urban drainage in the form of a useful reference document.

In addition, certain research projects have been sponsored by Central Mortgage and Housing Corporation. An intensive study has been undertaken by the City of Winnipeg, Manitoba to examine all aspects of the storm water impoundments constructed in that city. A systems demonstration study of storm water management technology in the City of St. Thomas, Ontario relates to urban drainage problems of local flooding, combined sewage overflows and sewage treatment plant by-passes.

These works have not only provided additional knowledge on the subject of urban drainage as it applies to Canadian conditions, but have given considerable impetus to the application of storm water management techniques all across Canada.

The Canada-U.S. Agreement has enabled a close association with the United States Environmental Protection Agency. Considerable

benefit has been obtained from the work done by that agency and the experience that they have gained, in providing a background for our own development work in this field.

Increasing attention is being given to methods of solving quantity and quality problems through the provision of upstream or downstream storage controls for combined sewer overflows and for inflow and infiltration. The importance of urban water shed management is becoming a vital factor in controlling pollution from street runoff and snow removal and disposal. The requirements and methods for possible storm water treatment are now being considered. It was not possible in the past to adequately correlate of all these factors into a unified approach to the subject, but with the assistance of the computer and the advent of the mathematical models this is now becoming possible. There is still much work to be done, however, in collecting background data and refining and calibrating some of the technical aspects of the computer programs in order to obtain the closest relationships to actual conditions.

As with other countries, until recently the main emphasis of pollution control in Canada has been on sanitary and industrial wastes. Increasing attention is now being given to the problems of urban drainage. There is no indication that Canada is lagging far behind in its efforts in this direction.

There has been a uniformity in the extent of the approach to the problem. Increased leadership, encouragement and support from senior levels of government are required before the ultimate goals can be achieved.

1. INTRODUCTION

1.1 Investigations

Much of the information on current urban drainage practices in Canada was assembled from a project undertaken by Environment Canada.

Replies to a questionnaire sent to regional offices across Canada by the Environmental Protection Service of Environment Canada were assembled and summarized. Responses were incomplete from all provinces and supplemental information was obtained where possible from alternate sources.

The Environment Canada questionnaire was divided into three categories of questions:

I - Design of New Sewer Systems

II - Abatement and Pollution Due to Combined Sewer Overflows

III - Field Studies of Sewer Systems.

1.2 Financial Influences on Current Policies and Practices

The financial assistance for urban drainage works provided by various agencies and authorities and available to municipalities across Canada was not covered by the questionnaire. Information available was considered, however, in relation to its influence on current policies and practices. The agencies and authorities from which assistance is available include the Central Mortgage and Housing Corporation and certain provincial departments in charge of agriculture, environment, highways, natural resources (conservation), etc.

1.3 Historical Commentary and Future Trends

Historical commentary has been limited to observations, mainly derived from the foregoing information, statistical data and from general observations made from engineering practice in the field of urban drainage practice. No attempt has been made to assemble a comprehensive historic review of urban drainage practice in Canada.

Future trends have been examined only on the basis of statistical growth and present engineering developments in this field.

1.4 Background Statistics

In order to give some feeling of relativity to the extent of the subject as it applies across the country, two tables of statistics are enclosed on the following pages.

Table 1 shows area and population figures, and percentage of population in municipalities of over 5,000 people. Table 2 shows the distribution of lower tier or single-government municipalities of various sizes. This information is derived from Canada Census figures.

1.5 Historical Background

The desire and necessity to take concrete steps to stop the deterioration of the environment focused initial emphasis on improving the quality of domestic and industrial wastes which were being discharged to the most convenient receiving water. Much time, effort and money has been expended in this direction and encouraging results are now being achieved.

Prior to this focus on the environment and the consequent upsurge in the construction of waste treatment facilities, disposal of surface water runoff and domestic and industrial wastes was made, untreated, to the nearest receiving water, often by means of a single combined sewer pipe.

With the advent of sewage treatment plant construction and continual pressure over the years to improve operational efficiency and economy, it became desirable to eliminate extraneous water from flows through the treatment plant. Construction of new separate storm sewers was commenced in areas having combined sewer systems in order to reduce or eliminate combined sewer overflows during times of storm.

This philosophy has been generally accepted over the years since World War II, and the rapid urban expansion during these years has seen new areas of development served by these separate systems of sewers. In many places these separate sewer systems are extensions of the original core area combined sewers.

TABLE 1 POPULATION DISTRIBUTION

Province	Area in 1000 Sq. mi.	Population in Thousands	Population Densities Persons/Sq.mi.	Population in Municipalities over 5000 in Thousands	Percentage of Population in Municipalities over 5000
Newfoundland & Labrador	143.5	522.1	3.64	166.5	31.9
Prince Edward Island	2.2	111.6	51.08	28.6	25.6
Nova Scotia	20.4	789.0	38.67	713.9	90.5
New Brunswick	27.6	634.6	22.96	605.9	95.5
Quebec	524.3	6027.8	11.50	4170.5	69.2
Ontario	354.2	7703.1	21.15	6501.6	84.4
Manitoba	211.5	988.2	4.67	678.7	68.7
Saskatchewan	220.1	926.2	4.21	391.1	42.2
Alberta	246.4	1627.9	6.61	1264.6	77.7
British Columbia	344.8	2184.6	6.34	1745.6	79.9
Yukon & N.W. Territories	1548.8	53.2	6.03	17.3	32.6
CANADA TOTAL	3560.2*	21568.3	6.06 Av.	16284.4	75.5 Av.

* Provincial land area totals do not add up to the total for Canada because of water areas.

NOTE: The above figures have been derived from the 1971 Canada Census. The 1976 Canada Census population is 22,598,600 for an average annual growth from 1971 to 1976 of 0.94 per cent. In comparison over the same 5-year period, the fastest growing provinces are, respectively: Alberta with 2.03%, British Columbia with 1.95% and Ontario with 1.09%. Saskatchewan declined by 0.41% and Manitoba and Quebec grew slowest with respectively 0.26 and 0.37 per cent.

TABLE 2 DISTRIBUTION OF MUNICIPALITIES BY SIZE

Province	Number of Lower Tier Municipalities*						
	Greater Than 250,000 Population	100,000 to 250,000	25,000 to 100,000	10,000 to 25,000	5,000 to 10,000	Less Than 5,000	Total
Newfoundland & Labrador	--	--	2	--	9	217	228
Prince Edward Island	--	--	--	1	1	99	101
Nova Scotia	--	1	2	14	27	50	94
New Brunswick	--	--	2	5	10	251	268
Quebec	1	2	28	54	60	1,457	1,602
Ontario	6	8	28	44	89	688	863
Manitoba	--	1	6	6	13	205	231
Saskatchewan	--	2	2	3	3	815	825
Alberta	2	--	4	8	30	338	382
British Columbia	1	1	12	30	25	135	204
Yukon & N.W. Territories	--	--	--	1	1	11	13
CANADA TOTAL	10	15	86	166	268	4,266	4,811

* Upper Tier and Lower Tier refer to levels of Government
e.g. Upper Tier - metropolitan or regional level of government
Lower Tier - city, town, village, township, etc. level of government

Over the years the trend has been to remove storm water from surfaces in urban areas as quickly as possible. This has led to the installation of larger and larger sewer pipes with increasing costs and also to increasing problems in downstream receiving waters due to erosion and contamination.

1.6 Recent Concerns

Research and investigation in recent years has shown that urban storm water runoff is not as harmless to natural receiving waters as had been previously assumed. The questions then arise - if it is going to become necessary to provide some form of removal of contaminants from storm water runoff prior to discharge to receiving waters, what form of treatment is required, where is this most economically done and is the separation of sewers still a viable solution to the problem? There are a variety of answers to this question which are highly influenced by conditions in various local areas, and unanimity may be very difficult to achieve. One response is to question the validity of storm water treatment as a basic assumption. This philosophy seems to have some favour, particularly in some of the larger Maritime cities where both untreated sanitary sewage and storm water runoff are discharged directly to the sea. Nevertheless, there is an increasing cognizance of the problems caused from storm water runoff and growing concern to find optimum solutions.

1.7 Canada-Ontario Agreement

A leading proponent of new ways to manage storm water run-off is the Urban Drainage Subcommittee of the Canada-Ontario Agreement on Great Lakes Water Quality. This subcommittee is made up of representatives from Environment Canada, the Ontario Ministry of the Environment and Central Mortgage and Housing Corporation. Over the past few years, it has investigated a considerable number of research and development projects in order to come to grips with the problems of quantity and quality of urban drainage. The preparation of a very comprehensive Urban Drainage Manual is the culmination of this work.

2. NEW SEWER SYSTEM DESIGNS

2.1 Sewer System Types

2.1.1 Classifications

Table 3 on the following page attempts to classify combined and partly combined sewers as compared with separate storm and sanitary sewers.

A combined sewer system can be defined as a system intentionally designed to carry both storm water runoff and sanitary wastewater. A partly combined sewer system is considered to be identical to a partially separated sewer system.

A partly combined system can be a combination of a system of combined sewers and a system of separated sewers. A partly combined sewer can be a combined sewer receiving, in addition to wastewater, storm runoff only from roofs and/or foundation drains; while an originally separate sanitary sewer, receiving storm water through later drain connections, may be considered a "perverted" sanitary sewer.

The replies to questions on partially combined sewers, therefore, may have different weights or meanings depending on how the recipient of the question defines a partly combined sewer or sewer system.

2.1.2 Level of sewer service in Canada

For a number of years, the Water and Pollution Control magazine has conducted an annual Canada-wide survey including statistics on pollution control.

From the data assembled in their 1975 survey, information on sanitary sewer service in Canada has been abstracted, as shown in Tables 4 and 5 on the following pages, including the extent of combined and partly combined sewer systems [2].

It should be cautioned that, due to the various interpretations of what constitutes a partly combined sewer system, the abstracted data may be limited in accuracy. Statistically, however, the data in Tables 4 and 5 may be considered sufficiently significant to indicate magnitude and to compare sewer service levels between provinces.

TABLE 3 CLASSIFICATION OF SEWER SYSTEM TYPES

Features	Combined Sewers	Partly Combined Sewers	Interconnected Storm & Sanitary	Separate Storm	Separate Sanitary
A. Flow Mixtures at Peak Flow Conditions	1 Part San. on 50-70 Parts of Storm Flow	1 Part San. on 10- 50 Parts of Storm Flow	1 Part San. on 5-20 Parts of Storm Flow	Storm Flow with traces of San. Flow	San. Peak Flow 2 to 4 times D.W.F.
B. Flow Sources Identification	Servicing all Storm and Sanitary Drain Connections	Part of Storm Flow mainly from catch basins, collected in separate "street sewers" San. flow plus balance of storm flow in partly combined sewer	Adjacent separate sewers interconnected intentionally for relief or incidentally such as from major leakage and infiltration	Except the odd incorrect san. drain connection storm sewer laterals are connected only Catch basin connections	Sanitary flow dilution very limited to normal incidence of inflow and infiltration
C. Other Features	Combined trunk sewers may receive flow from upstream san. or storm sewers	Sometimes original storm sewer receiving sanitary or combined flow from upstream	Interconnection in system may include san. and/or storm sewers draining into combined sewers	Storm flow only draining to open water by gravity	Sanitary flow conveyed to sewage treatment nearly always by pumping

TABLE 4 LEVEL OF SANITARY SEWER SERVICE

	Total Number of Municipalities (1971)	Total Number Served By Sanitary Sewers	Number Served In Part By Combined Sewers	Number Served Only By Separate Sanitary Sewers	Total Provincial Population 1000's	Total Population Served By Sanitary Sewers 1000's	Portion of Population Served By Combined and Partly Combined Sewers	Portion of Population Served Only By Separate Sanitary Sewers
Newfoundland	228	38	18	20	543.5	246.5	152.6	93.9
Prince Edward Island	101	6	2	4	115.3	43.8	28.9	14.9
Nova Scotia	94	42	16	26	807.4	320.8	179.2	141.6
New Brunswick	268	38	20	18	658.5	296.6	241.4	55.2
Quebec	1602	278	117	161	6119.1	4817.3	3573.6	1243.7
Ontario	863	307	79	228	8045.0	6155.9	2952.2	3203.7
Manitoba	231	113	24	89	1002.5	761.8	631.3	130.5
Saskatchewan	825	66	23	43	911.4	524.6	102.5	422.1
Alberta	382	85	20	65	1764.2	1267.7	515.2	752.5
British Columbia	204	81	16	65	2360.4	1712.2	629.4	1082.8
Yukon & Northwest Territories	13	4	1	3	61.4	17.6	2.0	15.6
CANADA	4811	1058	336	722	22388.7	16164.8	9008.3	7156.5

TABLE 5 COMBINED AND SEPARATED SANITARY SEWER SERVICE

	Total Provincial Population 1000's	Total Population Served By Sanitary Sewers 1000's	Percent of Total Population Served By Sanitary Sewers	Length of Combined Sewers (miles) *	Length of Separate Sanitary Sewers (miles) *	Total Length of Sanitary Sewers (miles) *	Percent of Combined Sewers (of Total Length) *	Percent of Total Population Served By Combined Sewers *
Newfoundland	543.5	246.5	45.4	249	550	799	31.2	14.1
Prince Edward Island	115.3	43.8	38.0	56	101	157	35.7	13.5
Nova Scotia	807.4	320.8	39.7	277	711	988	28.0	11.1
New Brunswick	658.5	296.6	45.0	412	550	962	42.8	19.3
Quebec	6119.1	4817.3	78.7	4310	7342	11652	37.0	29.1
Ontario	8045.0	6155.9	76.5	3451	10348	13799	25.0	19.1
Manitoba	1002.5	761.8	76.0	618	1057	1675	36.9	28.0
Saskatchewan	911.4	524.6	57.6	205	1257	1462	14.0	8.1
Alberta	1764.2	1267.7	71.9	551	2223	2774	19.9	14.3
British Columbia	2360.4	1712.2	72.5	691	3289	3980	17.4	12.6
Yukon & Northwest Territories	61.4	17.6	28.7	5	61	66	8.2	2.2
CANADA	22388.7	16164.8	72.2	10825	27489	38314	28.3	20.4

* Note: The quantities in these columns are approximations which have been estimated by means of extrapolation based on typical lengths of sewers to indicate relative trends.

From the data in Table 4, it can be seen that, while only approximately one-fifth of Canadian municipalities have sewer service, these municipalities contain three-quarters of the population. In Table 5, it is estimated that approximately 28 percent of all sanitary sewers consist of combined or partly sewers and from this figure it is calculated that approximately 20 percent of the Canadian population is served by combined sewers. This does not necessarily represent the proportion of population served by sewage treatment.

2.1.3 Separate sewer systems

Combined and partially separated sewer systems exist in most larger municipalities throughout Canada, but in all provinces separate sanitary and storm sewer systems are most favoured at the present time for new areas of development. In some locations, where a large portion of the municipality is presently served by combined sewers, it is not considered to be of sufficient advantage to generally provide separated systems for extensions into new developments unless there is a specific reason for this to be done, e.g. to prevent or relieve overloading of existing sewers.

In the Province of Quebec, for example, a 1970 development and management policy statement by the "Régie des Eaux du Québec" for sewer services outlines the following four cases for extensions of existing combined systems [3]:

1. More than two-thirds of the drainage basin is served by combined sewers, unless the existing system is under capacity and is separated or partly separated by relief sewers or separation is required for the protection of the receiving water.

2. Between two-thirds and one-third of the drainage basin is served by combined sewers. In general, separation is required unless the requirements of the receiving water afford development of a combined or partially combined system.

3. Less than one-third of the drainage basin is served by combined sewers. The remainder of the basin is required to be developed with separate sewer systems.

4. Unserved areas: New sewer systems are required to be separate.

From a study entitled "Review of Problems Within Combined or Partly Combined Sewerage Systems in the Province of Ontario" which has been concurrently undertaken by the Urban Drainage Subcommittee of the Canada-Ontario Agreement it was found that most combined sewer systems exist in the larger cities and were constructed mainly before World War II, when pollution control still was very limited and budgets for sewer construction were meagre. From certain test cases it appeared that, in general, the larger cities with partly combined sewer systems have completely combined sewer systems in their core and separate or partly separate sanitary sewers surrounding this core draining into the combined system.

2.2 Storm Sewer Design

2.2.1 Runoff quantity and quality

Runoff quantity has been the accepted basis for storm sewer design in the past and, in most of the provinces, is still the only consideration. Current literature and local, national and international conferences, however, have brought to the fore the growing concerns with respect to quality of runoff. Design based on quality as well as quantity is a relatively new practice, so far adopted or under consideration and study by major municipalities primarily in Ontario, Manitoba and Alberta. Conditions of pollution of open water, such as are more critical in Ontario, and of relatively flat land topography, such as prevalent in the prairie provinces, appear to provide the prime motivations for such more sophisticated design practice.

2.2.2 Attitudes and policies

The Ontario Ministry of the Environment, for example, has taken a lead in directing that, within the Regional Municipality of Ottawa-Carleton, the Rideau River and its tributaries could no longer be subjected to further pollutional loads. A report on the expected effect of storm drainage on the water course and the proposed method of control will be required for each new storm sewer outfall. This

requirement has been made because of the particular sensitivity of the Rideau River to changes in the surrounding environment due to planned and projected development.

The City of Winnipeg, Manitoba has also been shown concern by adopting a report on "Storm Water Management by Use of Impoundments" and by development of a "Drainage Criteria Manual for the City of Winnipeg" [5, 6]. The latter manual was prepared in 1974 and takes into consideration the current technology for storm water management.

Alberta Environment prepared and published in 1976 its "Objectives for Storm Water Management" for consideration by all controlling agencies, when new or proposed development is expected in order to "ensure the protection and rights of the downstream user against abnormal conditions created by storm water discharge from uncontrolled developments" [7].

The Ontario Ministry of the Environment, through a Working Committee with representatives from the Urban Drainage Subcommittee, municipal governments, Nova Scotia Technical College, the United States Environmental Protection Agency and various agencies of the Ontario Government, presented, in March, 1977, a draft of an "Urban Drainage Manual of Practice" as a forerunner of policies which it hopes to implement by the middle of 1978 [8]. The five objectives given were to:

- identify the magnitude and impact of urban drainage problems on the Great Lakes Basin;
- identify and describe new, innovative urban drainage concepts;
- present urban drainage problems and solutions in a framework of interagency cooperation;
- achieve urban storm water management; and
- contribute to the achievement of the general and specific water quality objectives for the Great Lakes agreed to by the Governments of Ontario and Canada.

Other provinces have shown varied degrees of interest with limited studies and research being undertaken. To some extent this interest may be related to amount of funds available and subsidies provided by higher levels of government.

2.2.3 "Natural drainage" principles

Natural drainage principles have found more favour in the western provinces where ponds and impoundments are utilized to slow runoff and to increase infiltration into the ground.

The prairie provinces of Manitoba, Saskatchewan and Alberta use retention ponds where possible as a major application of the natural drainage principle.

In British Columbia the interior municipalities and some lower mainland municipalities allow seepage pit disposal of roof and foundation drainage.

2.3 Storm Sewer Sizing

2.3.1 Design methods

2.3.1.1 Rational Method. The Rational Method for storm sewer design, introduced in 1889, has been, and still is, the most widely used method in Canada for calculating storm water runoff. The ability of the designer to adequately select a surface runoff coefficient and calculate a reasonable inlet time is highly dependent on his experience and familiarity with the local area.

2.3.1.2 Unit hydrograph methods. A unit hydrograph method correlating characteristics of measured sewer outflow hydrographs to synthetic unit hydrographs has been used in a few municipalities. It is understood that unit hydrographs have been developed for design for Halifax, Nova Scotia and for Granby, Quebec. British Columbia reported that unit hydrograph methods have been used by some consultants on a limited number of specific investigations.

2.3.1.3 Mathematical simulation models. Adoption of mathematical simulation models, such as the Storm Water Management Model (SWMM), Storage, Treatment, Overflow, Runoff Model (STORM) and Water Resources Engineers' model (WRE), are gaining ground and now receiving more attention from some designers. Other mathematical models of varying complexity have been developed and used to a limited extent by a few consultants.

Recently, a Canadian version of the SWMM model has been made available on a non-proprietary basis. This version is the result of the considerable research and development work undertaken by the Urban Drainage Subcommittee of the Canada-Ontario Agreement on Great Lakes Water Quality in order to provide modifications which would be applicable to particular aspects of the Canadian environment.

A number of the large consulting engineering firms are now familiar with these mathematical models and are increasing the utilization of them in new designs for urban drainage.

Most smaller municipalities do not have financial and technical resources readily at hand to undertake the use of computer models to aid in sewer design or analysis at the present time and, therefore, still rely heavily on the Rational Method, with design storms defined by intensity-duration-frequency curves.

To give a few examples of typical applications, mathematical models have been or are being used for the planning and design of new developments such as the eastern community of the City of Ottawa [10] and the south urban area in Nepean and Gloucester Townships adjacent to Ottawa. They are also being used in the design of the new Merivale Industrial Park in an existing, partially developed, watershed area in Nepean Township [11], and for the analysis of existing combined sewer areas in Cornwall and the Borough of East York in Metropolitan Toronto. The cities of Toronto and Vancouver have both engaged Dorsch Consultants to utilize their proprietary model in the analysis of each city's combined sewer system.

Figure 1 on page 15 shows an example of typical hydrographs of flow, and pollutographs of biochemical oxygen demand and suspended solids. These graphs were originally derived for the Merivale Industrial Park study to illustrate the results of the SWMM analysis with various degrees and methods of controls applied to the storm water runoff prior to discharge to the Rideau River.

2.3.2 Design storm

2.3.2.1 Definition. The selection of a design storm for the sizing of storm sewers is, basically, a planning decision and reflects the degree of convenience and safety required for use of the area under consideration. Some factors to be considered are:

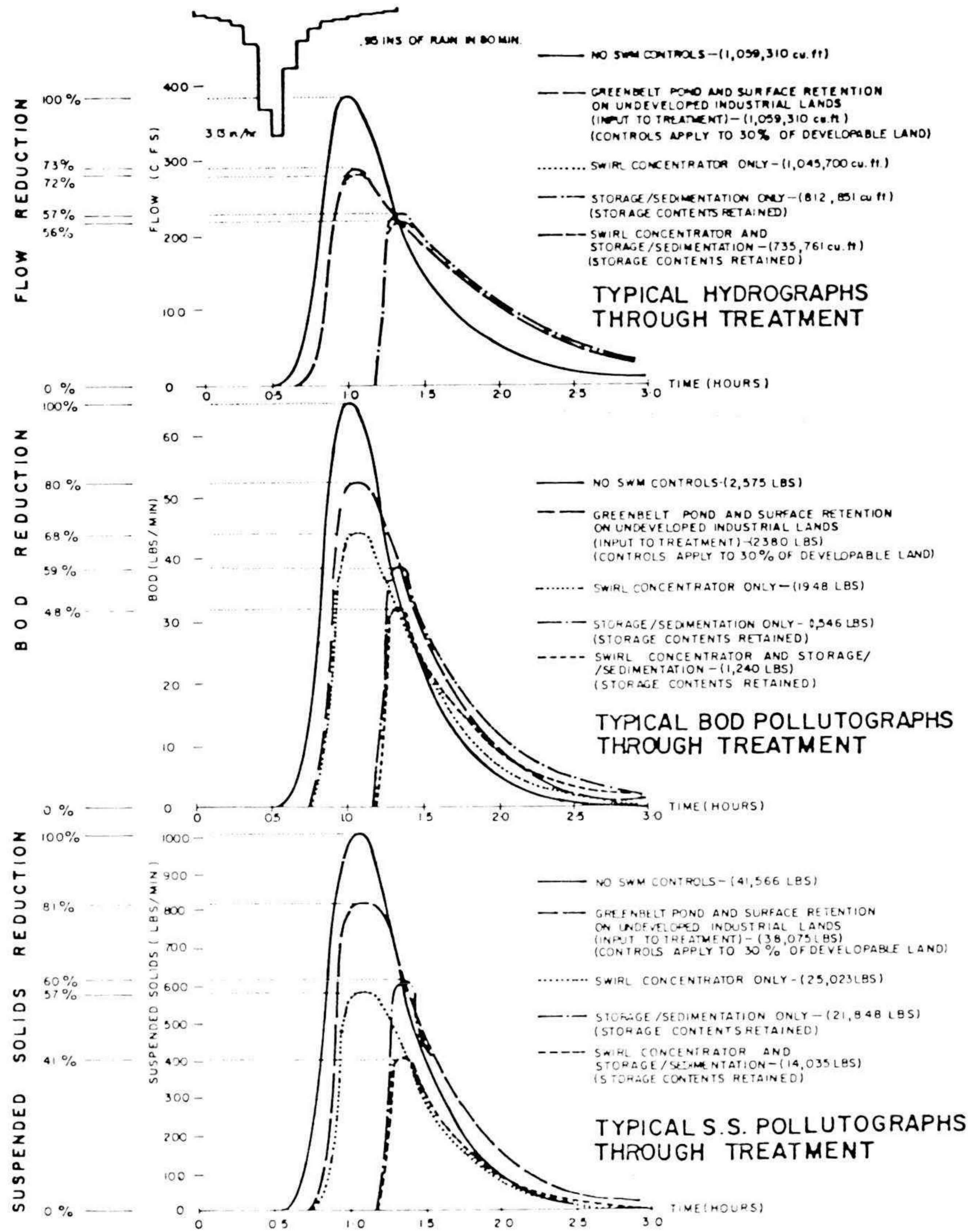


FIGURE 1. TYPICAL HYDROGRAPHS AND POLLUTOGRAPHS

- street maintenance,
- road traffic,
- health hazards,
- property damage, and
- benefits to be obtained in relation to cost.

The design storm may be selected in relation to the frequency of occurrence, rainfall intensity-duration curves, a storm hyetograph, an historical design storm, risk versus safety factor or water quality aspects of the storm water runoff. In general the quantity-based design requires return periods in the order of several years, while a quality-based design must consider return periods of several times each year in order to control the first flush pollution.

Intensity-duration-frequency curves such as those illustrated in Figure 2 on page 17, are most commonly used. In most cases such design parameters are developed by the consultants to suit each individual locality. Many years ago, sufficiently detailed meteorological information existed only in the largest cities and frequency curves used for other municipalities were often adaptations of the large city curves. Since 1968, the Canada Department of Transport, Meteorologic Branch publication of an "Atlas of Rainfall Intensity, Duration, Frequency Data for Canada" has afforded more accurate design graph preparation for any locality in Canada [12]. The atlas reflects a statistical review of long-term rainfall records and forms the basis of most local design curves developed by consultants and municipal engineers in the last 10 years. On occasion, curves are extrapolated using Gumbel probability to obtain frequencies of once in 50 or 100 years.

Storm hyetographs, showing the variation of rainfall intensity with time, are being used more frequently, particularly where rainfall volume must be considered for storage detention or retention. A hyetograph may be selected either from an actual storm obtained from precipitation records or from a synthetic design storm derived from rainfall intensity-duration curves as described above. It has been found that flows calculated from historical storms are consistently lower than those derived from the synthetic storms.

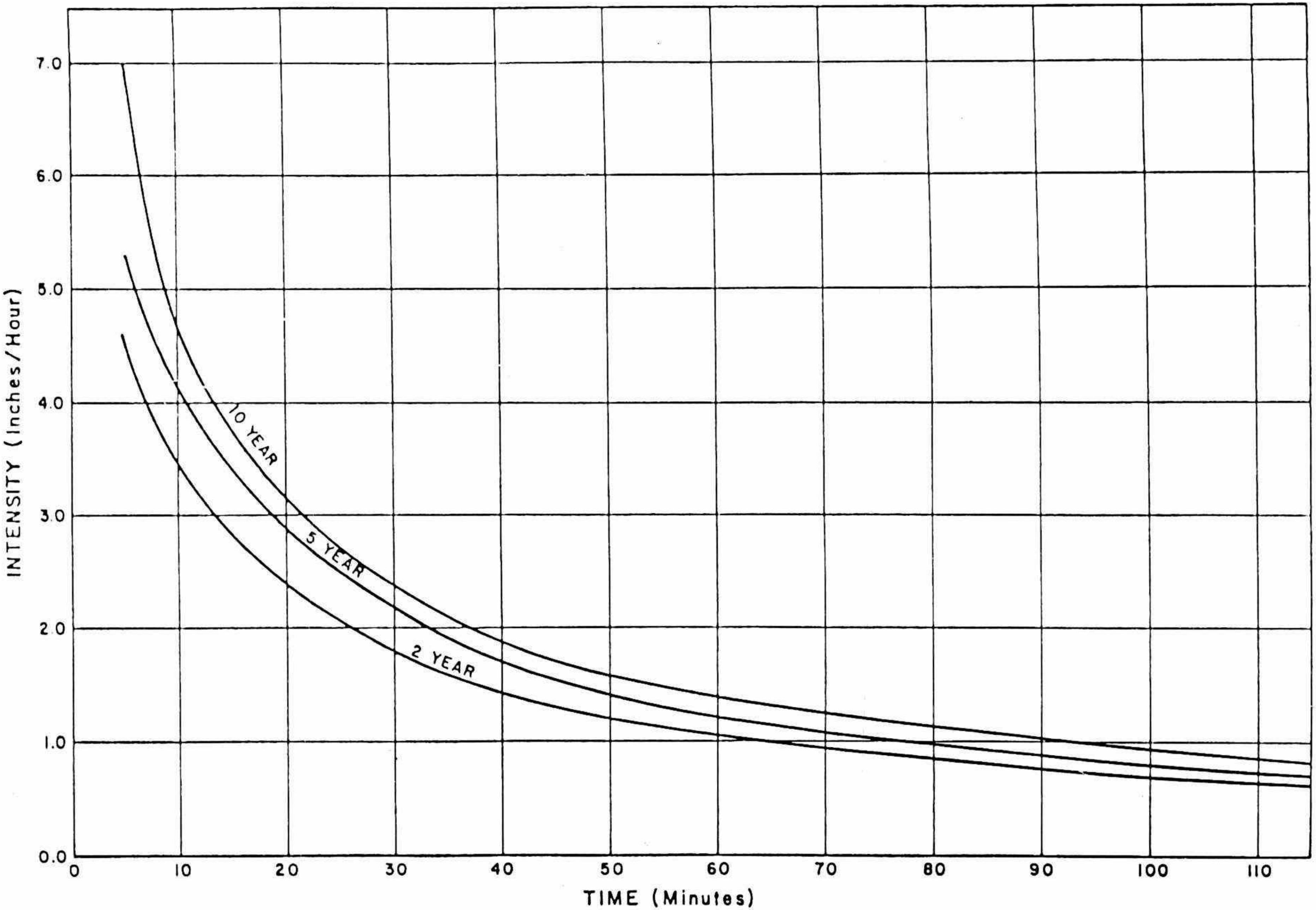


FIGURE 2. RAINFALL INTENSITY-DURATION CURVES

Actual and synthetic rainfall hyetographs, which were derived for the study of the development of the Eastern Community in the City of Ottawa, are illustrated in Figure 3 on page 19.

Definition of design storms by design storm hydrographs, again, is a relatively new development in sewer design. Methods are described under Chapter 4 of the manual of practice, "Design and Construction of Sanitary and Storm Sewers", which was prepared jointly by the American Society of Civil Engineers and the Water Pollution Control Federation. Only a limited number of consultants and municipal engineers have been reported to utilize these newer design methods for their practical application.

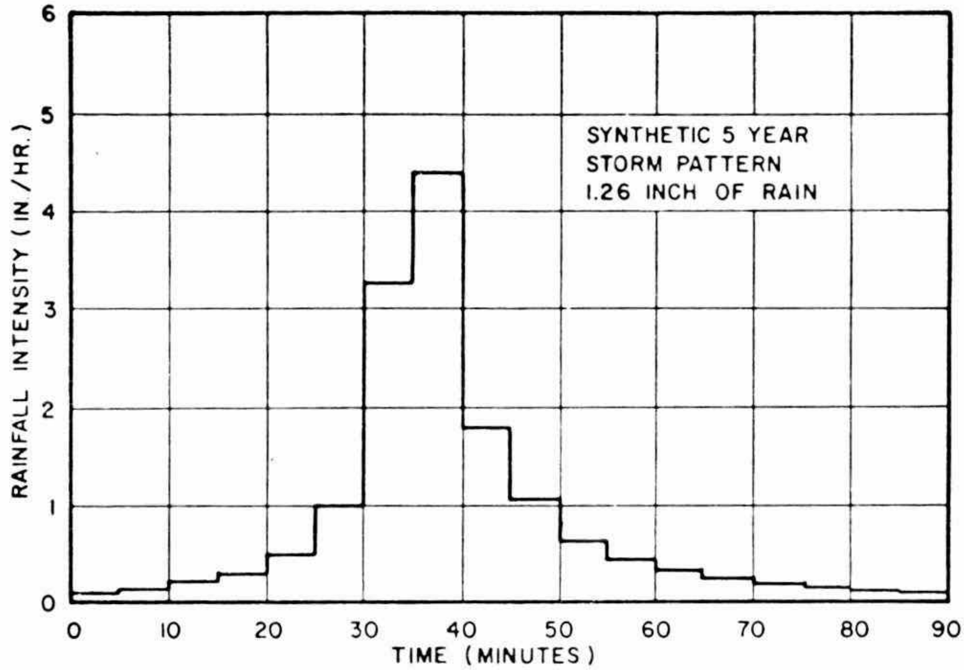
2.3.2.2 Design storm frequency. Frequency curves for storms occuring once in two years or once in five years are most often used for design. This is sometimes increased to once in 10 years for commercial and industrial areas. Enclosed conduits for water courses may be designed for frequencies of once in 25 years or once in 100 years. For open water courses where flood protection is critical, a frequency of occurrence of once in 100 years is used unless a "regional" storm of greater intensity has been recorded in the area.

It is doubtful that many culverts for driveways are actually hydraulically designed, except for special cases where ditches serve an abnormally large drainage area. Most such culverts are empirically selected and often dependent on what the municipality or developer has adopted as a standard size for a given type of development.

For minor road culverts storm frequencies of once in five years are possibly the most common.

For major road culverts, railway culverts and freeway culverts higher design frequencies, up to once in 100 years, may be used, varying with the authorities having jurisdiction and the standards adopted by them. In general, it may perhaps be observed that the storm frequency selection is dependent on the value of the traffic artery or adjacent property to be protected against flooding.

There is frequently a lack of uniformity of approach with respect to design methods and policies adopted by the various branches of government, which leads to much confusion for the designer seeking approvals.



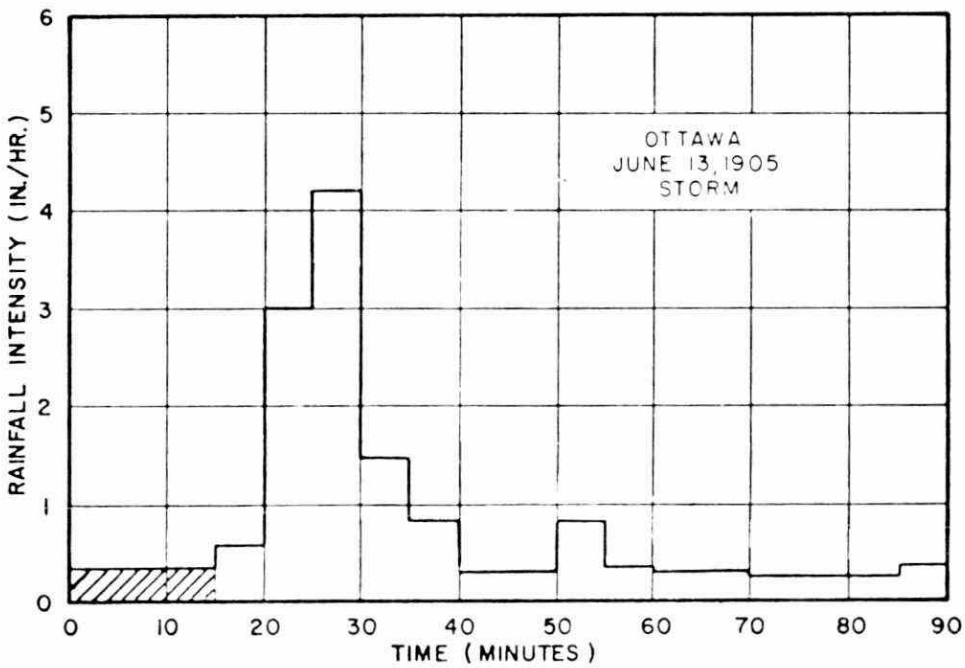
REF.:
"SYNTHETIC STORM PATTERN FOR DRAINAGE DESIGN"
C. J. KEIFER AND H. H. CHU
PROC. A.S.C.E. – AUG. 1957

BEFORE THE PEAK

$$i = \frac{a\left[(1-b)\left(\frac{t_b}{r}\right)^b + c\right]}{\left[\left(\frac{t_b}{r}\right)^b + c\right]^2}$$

AFTER THE PEAK

$$i = \frac{a\left[(1-b)\left(\frac{t_a}{1-r}\right)^b + c\right]}{\left[\left(\frac{t_a}{1-r}\right)^b + c\right]^2}$$



SHADED AREA ADDED TO OBTAIN THE SAME VOLUME OF RAIN (1.26 IN.) AS THE SYNTHETIC 5 YEAR STORM

CITY OF OTTAWA
EASTERN COMMUNITY

FIGURE 3. RAINFALL HYETOGRAPHS

2.4 Storm Water Detention

One of the deficiencies of the Rational Method is its lack of ability to compensate adequately for the effects of upstream storage in reducing peak runoff flows. The new mathematical simulation models are capable of taking into account these effects and a number of management techniques have been developed for creating this storage for evaluation by the model.

Such techniques include storage on streets and sidewalks, on rooftops and parking lots of industrial buildings, in parks and school-grounds, etc., which have been created by combinations of weirs and/or restricting orifices at inlets. Examples of such weirs and orifices are shown in Figures 4 and 5 on the following pages. Consideration must be given to the slopes of the storage surfaces and the depth of water permitted to accumulate.

Another device which has been receiving some attention recently is the Hydro-Brake System, which is a form of orifice control with storage designed to regulate a more or less constant rate of inflow of storm water into an existing sewer of limited capacity. This is achieved by providing a storage structure to which all storm water runoff is directed and which has the Hydro-Brake regulator on the outlet connection to the existing sewer. Some overall economies have been indicated by the use of this system. The Hydro-Brake System is being studied in the Township of Nepean under CMHC sponsorship.

The City of Winnipeg has developed storm water management techniques by the use of impoundments as a part of the planning for storm water storage and runoff. In many locations, these impoundments are designed to provide additional benefits as well, for recreational uses. In general, it has been found that the depth of storage should be limited to not more than four feet in residential areas but can be increased to six feet in industrial areas. In order to provide some degree of safety, the retaining embankment should not have side slopes steeper than 7:1. It is estimated that one cubic foot per second per acre at maximum discharge for a 50-year storm may be detained.

In Ontario, storage and detention techniques are being proposed in a number of locations. One example uses the Storm Water

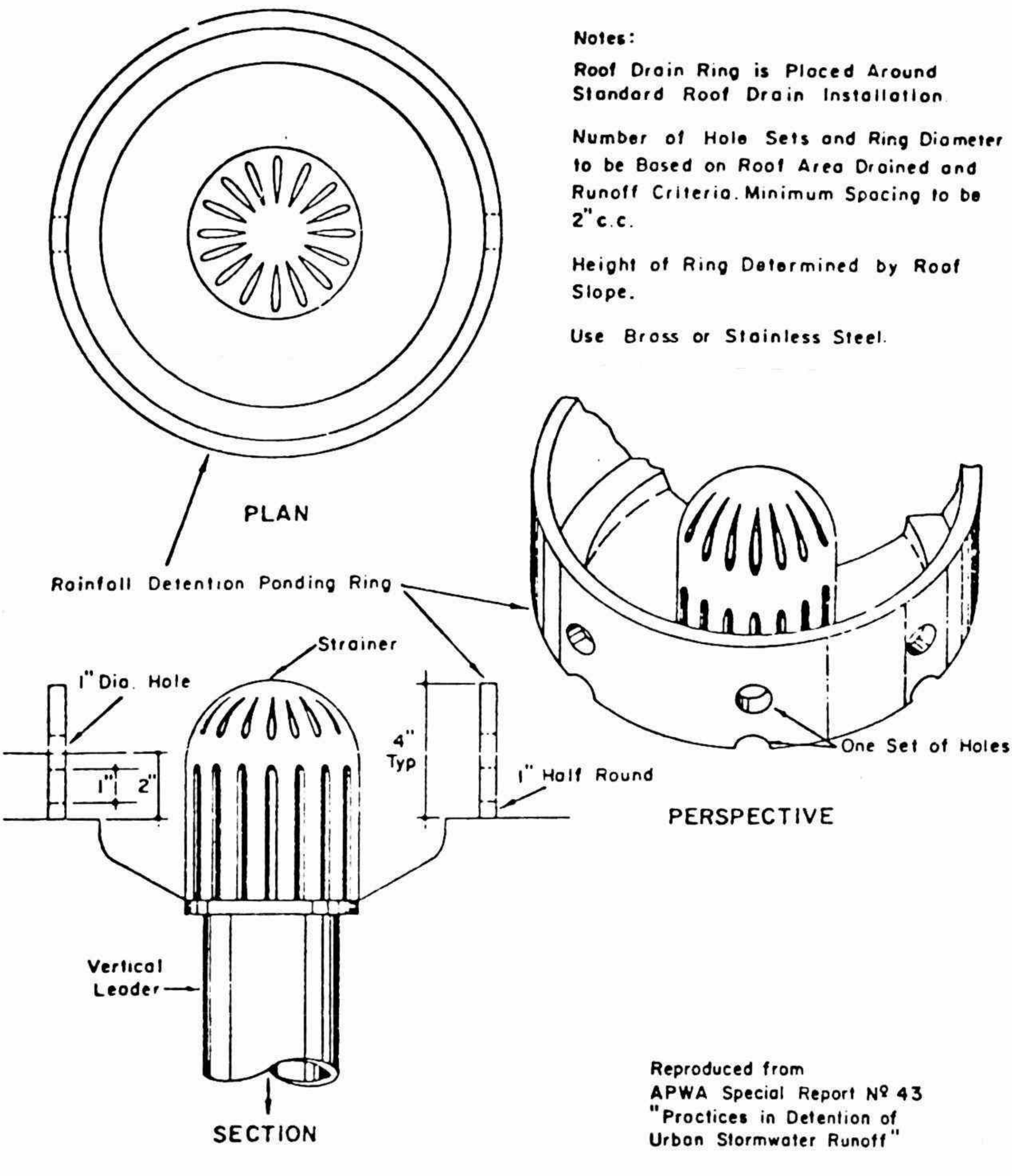
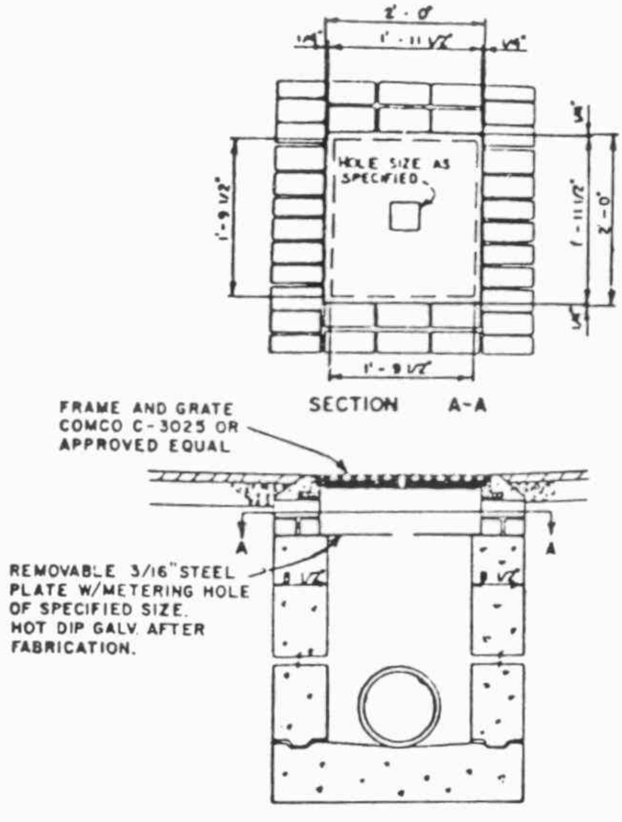
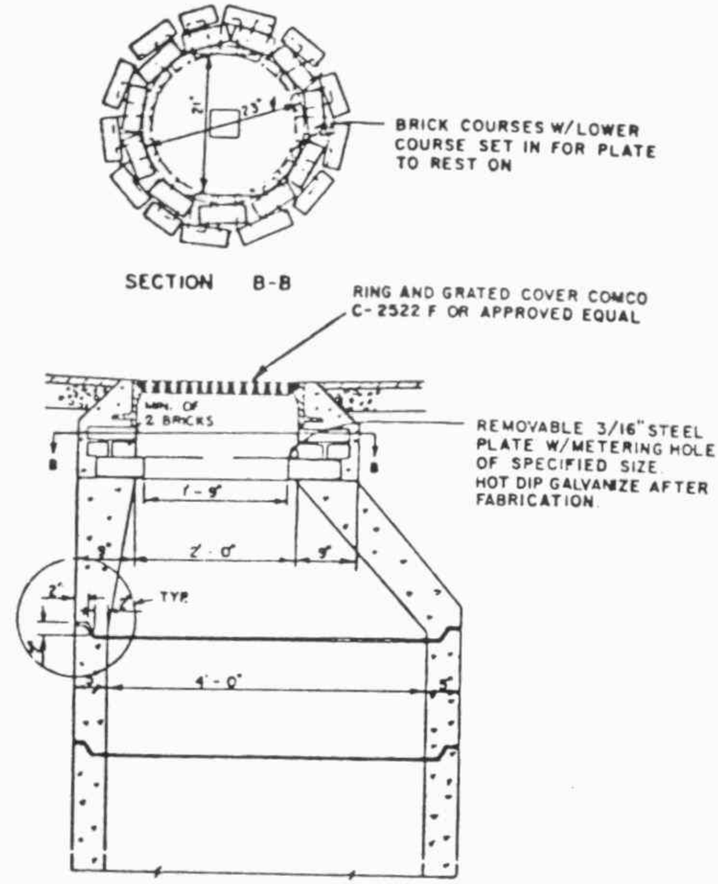


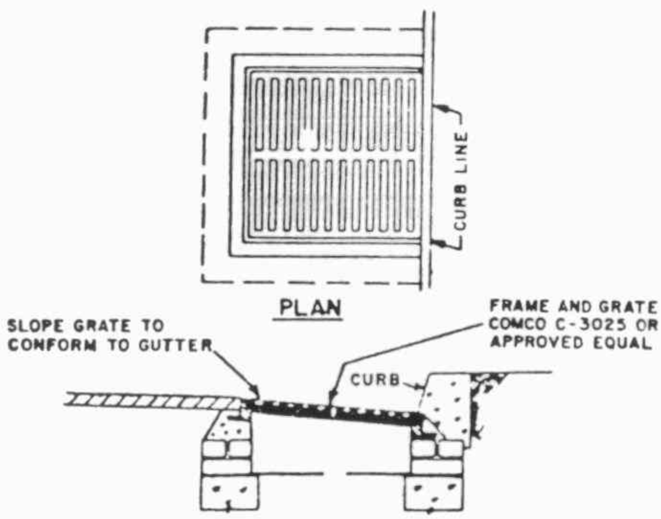
FIGURE 4. RAINFALL DETENTION PONDING RING FOR FLAT ROOFS



CONTROLLED RATE GRATED INLET



CONTROLLED RATE INLET
ON
CIRCULAR MANHOLE



CONTROLLED RATE GRATED INLET
AT CURB

Reproduced from
APWA Special Report Nº 43
"Practices in Detention of
Urban Stormwater Runoff"

FIGURE 5. CONTROLLED RATE INLETS

Management Model to analyze the effects of detention techniques on quantity and quality of runoff from the Merivale industrial area in the Township of Nepean in the Ottawa area. This has been particularly important because of the Ontario Ministry of the Environment requirements with respect to storm water discharges into the Rideau River and its tributaries. A pilot study of storm water detention in the Barrhaven area of the Township of Nepean has also been undertaken as a result of the same requirements.

Similarly, a research study has been made on storm water detention in the Meadowvale Lake in the Town of Mississauga just to the west of Toronto, and storage and detention techniques have been applied at the Upper Canada Mall Development in Newmarket, Ontario.

Alberta's recommendations have been incorporated in their published objectives. Nova Scotia indicated that detention was used only in some special cases.

2.5 Sanitary Sewers

In general, sanitary sewer systems for municipalities are all designed on the basis of utilizing gravity sewers, especially if lift stations and force mains are considered an integral part of the gravity sewer system.

Pressurized sewer systems include a system of relatively small diameter pipes into which the wastes from each building are discharged by means of a sump pump. It would seem to have limited application for some subdivision developments which could not otherwise be serviced by gravity sewers. Such a system was reported to be servicing an area of 26 houses in West Vancouver. A similar system was scheduled to be in operation December, 1977 in Temagami, Ontario serving 150 houses.

A number of communities in Saskatchewan were being serviced by low pressure sewage systems where septic tank effluent was pumped either into an adjacent municipal gravity sewer system or directly into a community sewage lagoon. A sewer tax may be levied not only to cover the cost of maintenance of the sewer mains and lagoon but, in some instances, to include annual inspections of the home-owner's pump installation and biennial septic tank cleanouts.

Vacuum systems work on the opposite principle to the above in that houses are connected to a central station where a vacuum pump sucks the flow in the system to a storage container from which it is pumped for disposal either to a tile bed or to an adjacent municipal gravity sewer system. As for the pressurized system, the vacuum system would seem to have a limited application. Again, such a system was reported to be servicing a number of houseboats at False Creek in the Vancouver area.

Both pressurized systems and vacuum systems have received some consideration for application to the servicing of summer cottages and trailer parks in the resort areas of Ontario.

2.6 Partially Separated Systems

Considering the previous classification of partially separated systems it was desired to learn the sources of sewage which drain into sanitary and storm sewers, respectively.

Most provinces indicated that it was general practice Canada to connect wastewater drains from dwellings and commercial and industrial buildings to sanitary sewers. Domestic sanitary drains carry primarily bath and wastewater discharges.

Storm sewers normally would carry the surface runoff, including the discharges from roof drains, as well as receive groundwater collected in foundation drains.

In some localities roof water has been permitted into a partially separated sewer along with the foundation drains. The City of Halifax, for example, has an old by-law requiring roof rain water leads to be connected to the sewer in the street. In most cases, however, it is favoured for the roof rain water to be discharged onto the ground.

The City of Toronto has had a plan of construction for a number of years whereby a new system of storm relief sewers and local street sewers is constructed to take surface runoff. Roof water and foundation drainage continue to discharge to the original combined sewer along with the sanitary wastewater. As old buildings are torn down or renovated for redevelopment the internal plumbing is required to be separated.

Due to an unusual situation of jurisdiction in the County of Halifax, Nova Scotia, a two-pipe system was installed by the County for local sewers. One pipe received the sanitary wastewater, the other pipe, called a "clearwater" sewer, received roof water, basement drainage and foundation drainage. Surface storm water runoff came under the jurisdiction of the Department of Highways and was either carried in ditches or shallow storm sewers.

In new subdivisions at Brampton, Ontario, a three-pipe system of sewers was installed wherein a sanitary sewer was installed at sufficient depth to collect sanitary drainage from the houses, and a second sewer pipe was installed at a similar depth to collect only the drainage through weeping tiles from around the building foundations. A third storm water pipe was installed at a shallower depth to collect surface storm water runoff. Where necessary, roof rainwater leaders can be connected to this shallow storm sewer.

In the Province of Quebec practically all foundation drains and most roof drains are connected to sanitary sewers and are the cause of major problems. Future policy is directed towards the design of partially separated sewers to eliminate these drain connections from the sanitary sewer.

Saskatchewan reported that weeping tiles are connected to sanitary drains in the areas without storm sewers.

An alternative solution that is sometimes used is to connect rain water leaders directly, by a shallow connection, to the storm sewer in the street and install a sump pump in the basement to lift foundation drainage to this shallow connection. Backflow from a surcharged storm sewer must be kept from reaching the foundation drains.

3. COMBINED SEWER OVERFLOWS - POLLUTION AND ABATEMENT

3.1 Pollution

It seems evident that municipal officials are more concerned with the quantitative problems than the qualitative problems of combined sewer overflows. The concern of provincial regulatory bodies with the qualitative problems of pollution and erosion of combined sewer overflows has not received the same emphasis at the municipal level. These attitudes of the different levels of government seem to be similar in the various provinces across Canada.

There may be several types of direct outlets to receiving waters in any given sewer system, some of which may be controlled or semi-controlled, others which may serve only for emergency relief purposes when pipes become over-taxed.

Relief overflows are quite common in combined sewer systems but are sometimes also provided in sanitary systems, especially when high infiltration conditions exist.

Other than at pumping stations and plants, most larger combined sewer systems may have overflows at system interceptions. An interceptor sewer conveys the dry weather flow to the treatment facility and is most often limited in capacity to an order of three to four times the dry weather flow. During storms, all excess flow is discharged to open water, usually via many existing original outfall sewers along the water front.

Very seldom do measuring or control devices installed in the intercepting manholes afford the assessment of the extent and frequency of overflows and, consequently, the significance of the pollutional aspect.

In the Maritimes, it was indicated that, although combined sewer overflows may be a major source of pollution, it was considered that in most instances it was not significant in relation to other sources of pollution. It particularly was not a significant source along the coastline except in the vicinity of shellfish beds.

Since combined sewers exist in only a few cities on the western prairies, it was felt that the overflow from these sewers was not the major source of pollution in relation to other sources.

Manitoba estimated that combined sewer overflows constituted approximately only 25 percent of the total sewage load discharged to receiving streams.

Quebec also believed these overflows were not a major source of pollution except where they may occur near water intakes. In British Columbia, the magnitude of the problem seems to be related to the receiving water. It is assumed that this would probably refer to inland municipalities on rivers and to seacoast municipalities.

Saskatchewan reported that combined sewers are virtually non-existent. (Table 5 shows that this Province has one of the highest percentages of separate sewer systems in Canada, but still has a measurable quantity of combined and partly combined systems.)

Ontario is concerned about the pollutional aspects of combined sewer overflows. As a part of the problem definition activity of the Urban Drainage Program of the Canada-Ontario Agreement on Great Lakes Water Quality, a report on "Evaluation of the Magnitude and Significance of Pollution Loading from Urban Storm Water Runoff - Ontario" was submitted by the American Public Works Association (APWA). This project studied the cost effectiveness of storage and treatment, combined sewer controls, primary and secondary devices for control of runoff and the relation of wet-weather control and dry-weather treatment for control of pollution to receiving waters. It was found that overall costs for solving flooding and water pollution problems associated with existing urban drainage systems will be several billions of dollars.

3.2 Policies

Most of the provinces do not have any fixed policy established on the control of combined sewer overflows. Where unofficial standards are practiced, they are generally based on discharge quantities.

The Province of Quebec has provided 100 percent subsidies for municipalities undertaking master drainage plan studies. Saskatchewan reported that overflows, where possible, are only approved for emergencies.

Ontario does relate controls to the receiving water quality and use. As a matter of policy, the Ministry of the Environment requires all overflows and by-passes of sanitary sewage to be effectively eliminated as far as this can possibly be done by provision of adequate capacities and auxiliary stand-by power.

3.3 Control by Separation

In the late 19th century the installation of separate sanitary sewers was approached as an economic consideration with respect to treatment plant operation. Where combined sewers had been installed, however, it soon became apparent that there were enormous costs for complete separation both of street sewers and internal building plumbing systems. For a while the treatment and purification of water supplies seemed to be an acceptable substitute. Some partial separation has been used to relieve basement flooding in problem areas.

The policy of constructing separate sewers for new installations has been almost universally adopted across Canada with only a few exceptions which have been mentioned earlier.

The problem of separation of flows in municipalities having combined sewer areas has received considerable discussion. Until recently, it was considered that separation was practically the only technique available to effectively eliminate overflows from combined sewer systems. One technique, as utilized by the City of Toronto, involves the installation of trunk storm relief sewers and new local street sewers to direct a large portion of the storm water runoff away from the combined sewer system and into a separate storm sewer system for discharge directly to Lake Ontario.

Sewer separation has been adopted as a general policy in the Provinces of Quebec, Saskatchewan and British Columbia and is also practically the only technique used in the Maritime provinces.

Although sewer separation is widely used in Ontario and Quebec, it is not considered to be the only technique for overflow control. Similarly, in Manitoba, separation is only one of several techniques.

3.4 Control of Inflow and Infiltration

Inflow is generally described as that water which is discharged into sewer lines from rain water leaders, basement drains, foundation drains, commercial and industrial clean water discharges and any surface waters which are deliberately directed to the sewer. This is distinguished from infiltration, which is considered to include groundwater which may be entering the sewers and house connections through defective lateral connections, defective joints, broken and cracked pipes, leaking connections through manhole walls, etc.

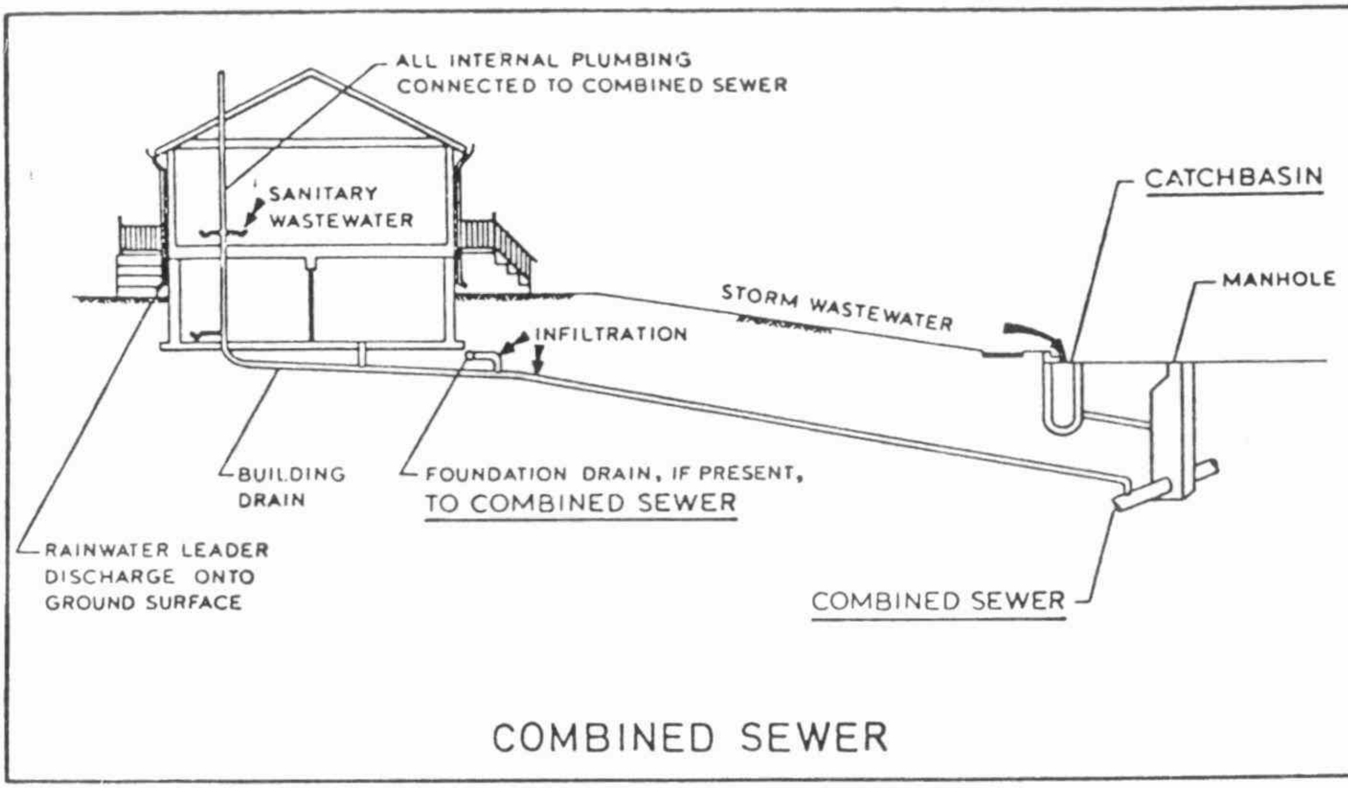
As was indicated earlier, inflow and infiltration are the most widespread of the combined sewer problems in Ontario.

3.4.1 Inflow

3.4.1.1 Roof drainage. The connection of roof rain water leaders to sewer systems is one of the most controversial problems of inflow to sewers. In past years, it has been a common practice in many municipalities to connect rain water leaders to foundation drains and then to the sewers in the street. Sometimes, these street sewers were separate storm sewers and sometimes they were combined sewers. In many instances, where only a sanitary sewer was available in the street, the drains have been connected to this pipe. It is now generally conceded that rain water leaders should not be connected to sanitary sewers and many municipalities no longer require this to be done. Some places have even made it a requirement that rain water leaders be discharged onto the ground at a certain distance from the house or building. Illustrations of typical building connections are shown in Figures 6 and 7 on the following pages.

New Brunswick, as in the other Maritime Provinces, indicated that rain water leaders should discharge onto the ground for seepage into the soil. There are a few instances in the Maritime provinces where they are permitted to be piped to street gutters or surface ditches. A City of Halifax by-law still requires rain water leaders to be connected to the street sewer although this by-law may not be as closely enforced as it once was.

In most municipalities in Ontario, the requirements are for connection to storm sewers or, in some places, for disconnection for



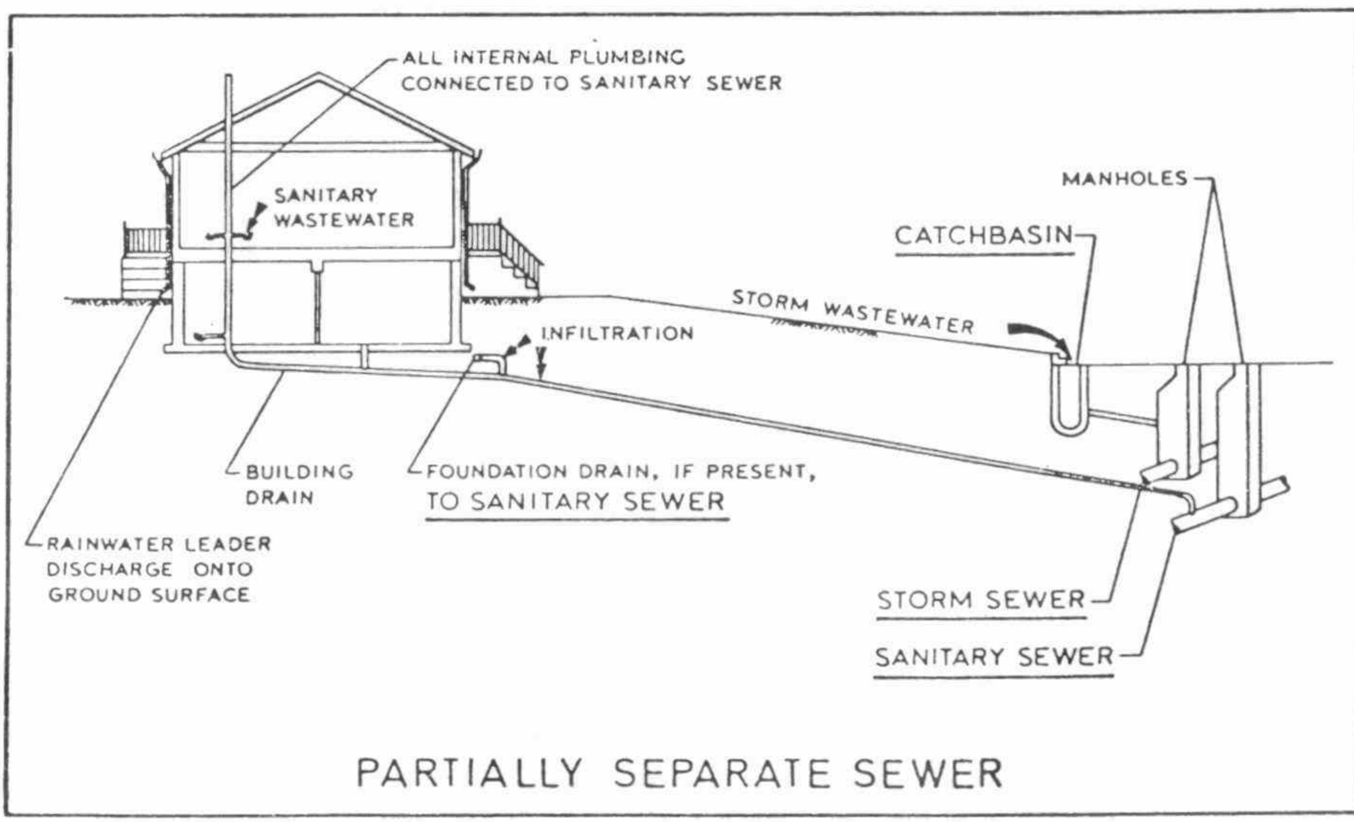
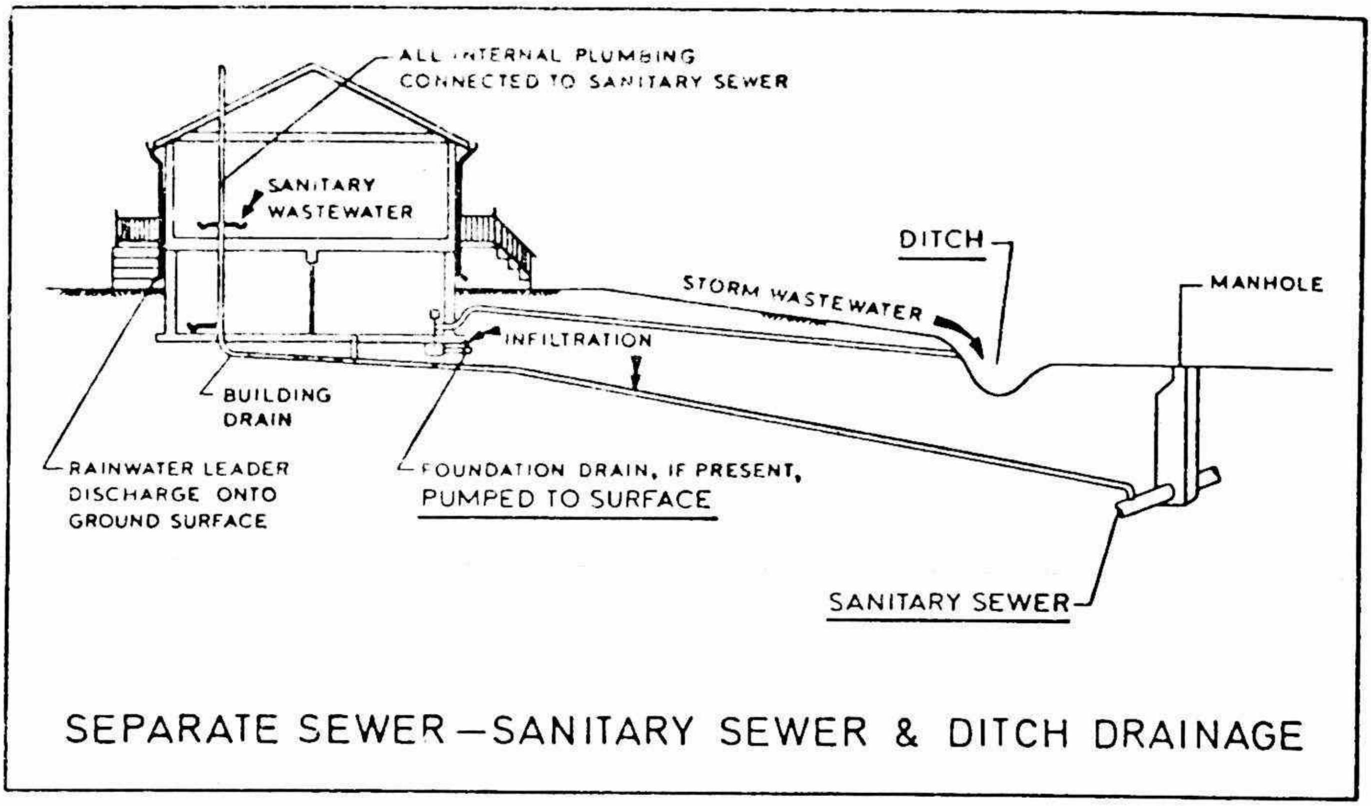


FIGURE 6. BUILDING CONNECTIONS - COMBINED AND PARTIALLY SEPARATE SEWERS



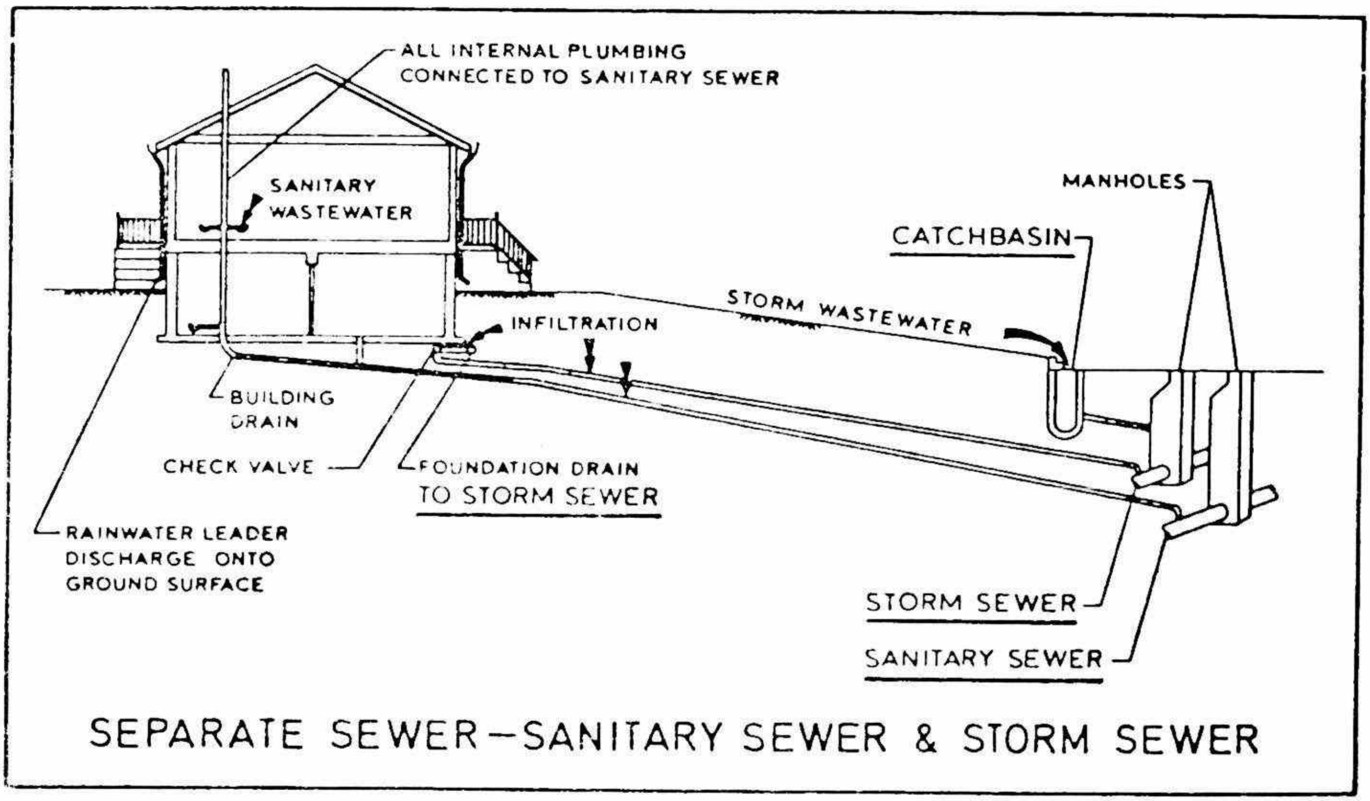


FIGURE 7. BUILDING CONNECTIONS - SEPARATE SEWERS

discharge onto the ground. A similar practice seems to prevail in Saskatchewan and in British Columbia. Manitoba indicated a preference for roof drainage to be discharged on the ground for seepage into the soil or to find its way to the street gutters.

Only very few municipalities have attempted a program to detect where roof drain connections to sanitary sewers exist or to enforce or subsidize the disconnection of roof drains from sanitary sewers. Many homeowners dislike the problem of wet and soggy lawns caused by the discharge of downspouts on the ground and resist having them disconnected from the foundation drains. More publicity is necessary to make the general public aware of the advantages of disconnection, and the problems and costs occurring because of these connections.

3.4.1.2 Foundation drains. Foundation drain connection practice has been indicated to be under municipal control, with connections to storm sewers favoured but to combined sewers or sanitary sewers permitted under particular circumstances.

In general, foundation drains are connected to the sewer in the street and it does not seem to matter too much, as far as municipal regulations are concerned, to which type of sewer the drains are connected. Each province seems to have its own preferences but there is no uniformity across the country.

Connection of footing drains to sanitary sewers is more prevalent than connections of roof drains. Whereas connection of roof drains to sewers is primarily a convenience, foundation drains are often considered necessary to protect basements from damage which may be caused by water pressure and uplift due to high levels of groundwater. If a deep storm sewer is not available, then connection to a deep sanitary sewer will save the expense of constructing and maintaining a sump to pump into higher storm sewers or ditches.

Problems occur, however, when the street sewers are surcharged during times of peak flows or storm runoff. At these times, the surcharge in the sewer backs up the house connection and, if there is insufficient vertical distance between the sewer and the building foundation, the surcharge will percolate from the foundation

drains into the ground around the basement walls. There the roof drains are connected to the foundation drains, in this instance, the situation is compounded. It is even further compounded if the street sewer is a combined sewer or a separate sanitary sewer.

In one area of the City of Ottawa, foundation drains are connected to three-part basement sumps. The foundation drain is connected to the central sump from which it can flow into another sump containing a backwater valve. During times of dry weather flow, the foundation drainage flows through this second sump by gravity to the street sewer. When the street sewer is surcharged by high flows, the backwater valve or flap gate closes, and the foundation drainage flows into the other compartment which contains the sump pump. The sump pump is either connected to the drain to the sewer or discharges on the surface of the ground. Only a few houses in the sub-division have this type of facility and these were reported as not always completely successful in operation.

In Manitoba, there are locations where foundation drains are connected to the sanitary sewers and major flooding of basements has been experienced as a result. British Columbia has found that these discharges to sanitary sewers in the older developed areas are very difficult to rectify. Present Quebec policy is to discourage the practice of connecting roof and foundation drains to sanitary sewers.

Here again more adequate dissemination of information to show the disadvantages and problems is required. This is perhaps aggravated by the limited availability of good factual information on the flow contribution of footing drains to sewers and to what extent such connections cause sanitary sewers to be overloaded.

3.4.1.3 Sewer use regulations. Generally, the connection of roof and foundation drains is regulated by municipal sewer use by-laws. Under these regulations, new development in municipalities would be required to either drain roof downspouts onto the property for seepage into the soil where soil conditions are favourable, into surface ditches where these exist, or into storm sewers.

A number of municipalities have adopted regulations requiring lot grading to slope away from the building and/or downspout

outlets for a certain minimum distances away from the building. In areas with heavy clay soils, discharging downspouts onto the property surface is often impractical. In such cases, connections to surface ditches or storm sewers would be the most common modern practice and be required by-law.

The level of enforcement of such by-laws can vary appreciably. The existence of adequate by-laws does not necessarily warrant that good drainage practice is exercised in this respect.

Comments on poor or slow enforcement of the regulations have been made by a number of provinces and may be assumed to apply Canada-wide.

3.4.1.4 Control of surface runoff quantity. There is a general indication of a trend towards controlling the surface runoff quantity by taking advantage of existing natural drainage in urban planning, often using surface ponding through detention ponds or impoundments. At the present time, this has mostly been done by progressive developers on a voluntary basis.

Nova Scotia and New Brunswick indicated some planning for control by natural drainage techniques. In Ontario there is some use of natural drainage in urban planning although at present it is not widespread.

Maximizing runoff seepage into soil, and ponding have not yet been generally adopted or implemented.

In Manitoba, runoff is directed away from houses by exaggerated lot grades of two percent to four percent to overcome long-term lot settlements around the houses. It had been observed that the dish effect of such settlement has been the prime source of runoff entering foundation drains. The City of Winnipeg has made a policy of impoundments for the storage of surface water runoff. Wherever possible, such impoundments have been developed into recreational and landscaped features.

3.4.2 Infiltration

A few municipalities in Canada have attempted to control infiltration through municipal sewer use by-laws. Even where this

is not controlled by an official by-law there is generally a standard of practice with respect to control of infiltration. The requirements are generally directed through either the engineering design standards set up by the municipalities or the consulting engineers' specifications.

In an attempt to control the quality of sewer pipes, the provinces of Ontario and Quebec have set out prequalification requirements for pipe manufacturing companies.

Usually leakage tests are specified to be undertaken at the time of construction. There is some variation in the methods to be used in conducting these leakage tests. For example, a typical procedure in Ontario is for the sewers to be tested upon completion of installation and backfilling, either by an exfiltration test or an infiltration test, depending on the level of the groundwater table. The amount of leakage allowed for an infiltration test may be specified at 0.25 gallons per inch of diameter per 100 feet per hour or an equivalent in other units. This allowable leakage may be increased 25 percent for exfiltration tests plus an allowance of 0.2 gallons per hour per foot of head above the invert for each manhole included in the test section.

In the Maritimes, the general practice for leakage tests is exfiltration tests made prior to backfilling. This is done to permit the contractor to rectify the leaks prior to completing the installation and backfilling.

One of the biggest problems with infiltration is often in the section of private drain between the street line and the house which is not included in the normal leakage test and where there is a minimum of inspection and control.

Where infiltration is observed in existing sewers, it can often be corrected by the use of TV inspection and the injection of "M-9" grout into the leaking joints. The City of Toronto has developed a technique for inserting a new polyethylene liner into an existing sewer pipe where infiltration has been excessive.

3.5 Control by Overflow Regulators

In certain areas where overflows from combined sewers cannot be avoided, it is necessary to provide some form of regulator to control flow to the treatment facility. Such regulators are generally set to permit overflows from the combined sewers when the rate of flow exceeds three to four times the dry weather flow (DWF) on the average, although the variations range from 2.75 to 8.0 times the DWF.

In some instances, a sewage pumping station may be considered as a form of regulator in that the discharge is limited by the pump capacities. Fixed orifice controls have been utilized in the City of Kingston. Side overflow weirs are probably the most common form of regulator. In the City of Toronto the side overflow weirs are combined with a submerged underflow weir or orifice to control the amount of flow retained in the existing combined sewer according to its capacity. This is illustrated in Figure 8 on the following page.

The Municipality of Metropolitan Toronto has recently installed a new interceptor to receive flows from the City's combined sewers. The intercepting structures are designed to divert the combined sewer flow into a control structure which will regulate the discharge to the deep intercepting sewer. The inlet to the structure is controlled by calibrated sluice gates and the discharge flows out through a vortex chamber in a regulated flow to drop through a vertical downpipe. This arrangement is shown in Figure 9 on Page 38. As a storm moves across the Metropolitan area, the flows in the combined sewers will peak at different times. The operation of this facility is such that, by controlling the sluice gates in the intercepting chambers to permit maximum diversion of combined sewer flows from each combined sewer as the peaks are reached, the maximum capacity of the intercepting sewer can be utilized. This system could also be considered as a form of quality control for the combined sewer system.

3.6 Innovative Solutions

3.6.1 Computer control systems

The intercepting system installed for the Municipality of Metropolitan Toronto, as described above, is being planned for the possibility of eventual computer control.

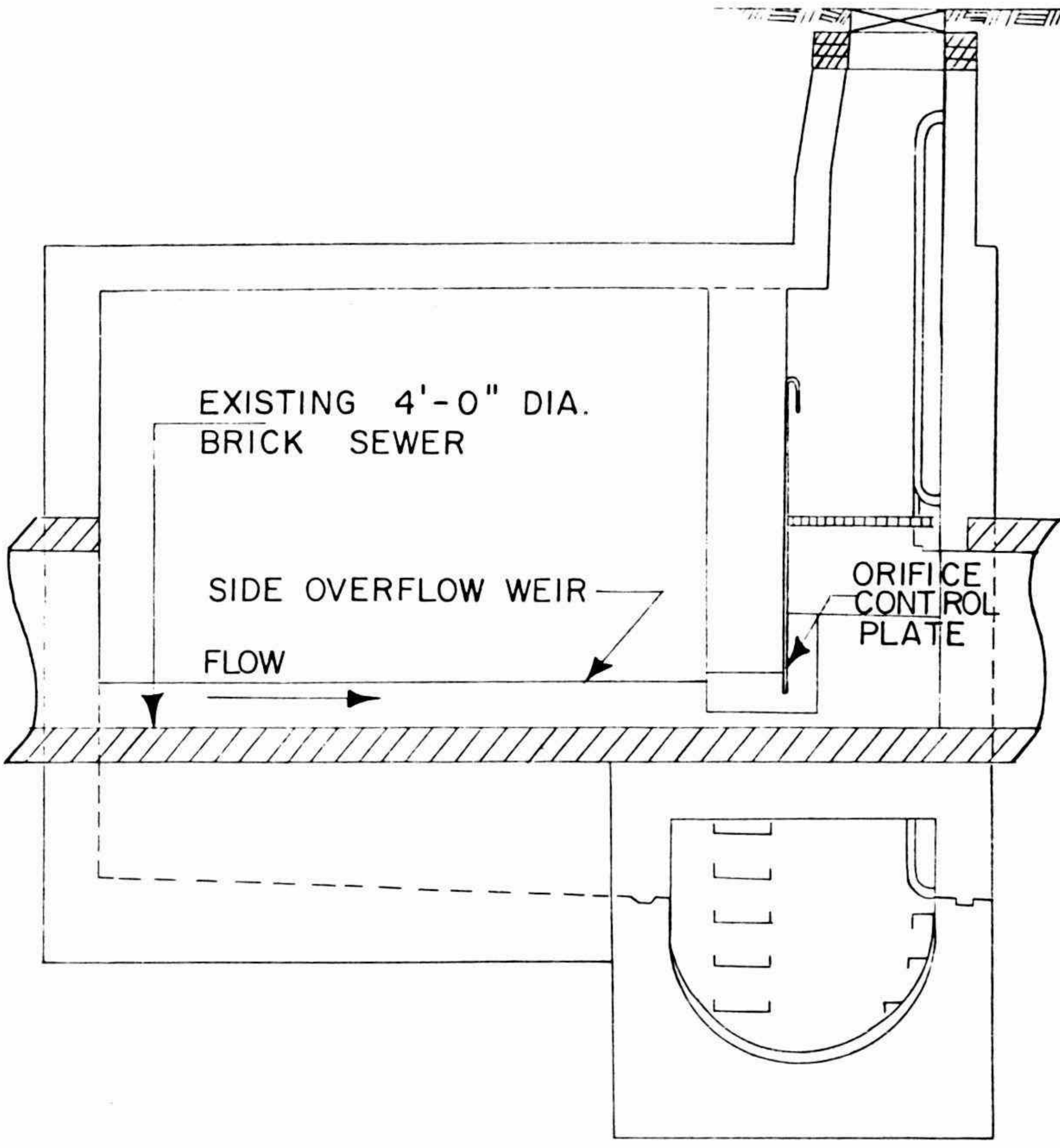


FIGURE 8. TYPICAL SIDE OVERFLOW WEIR CONTROL

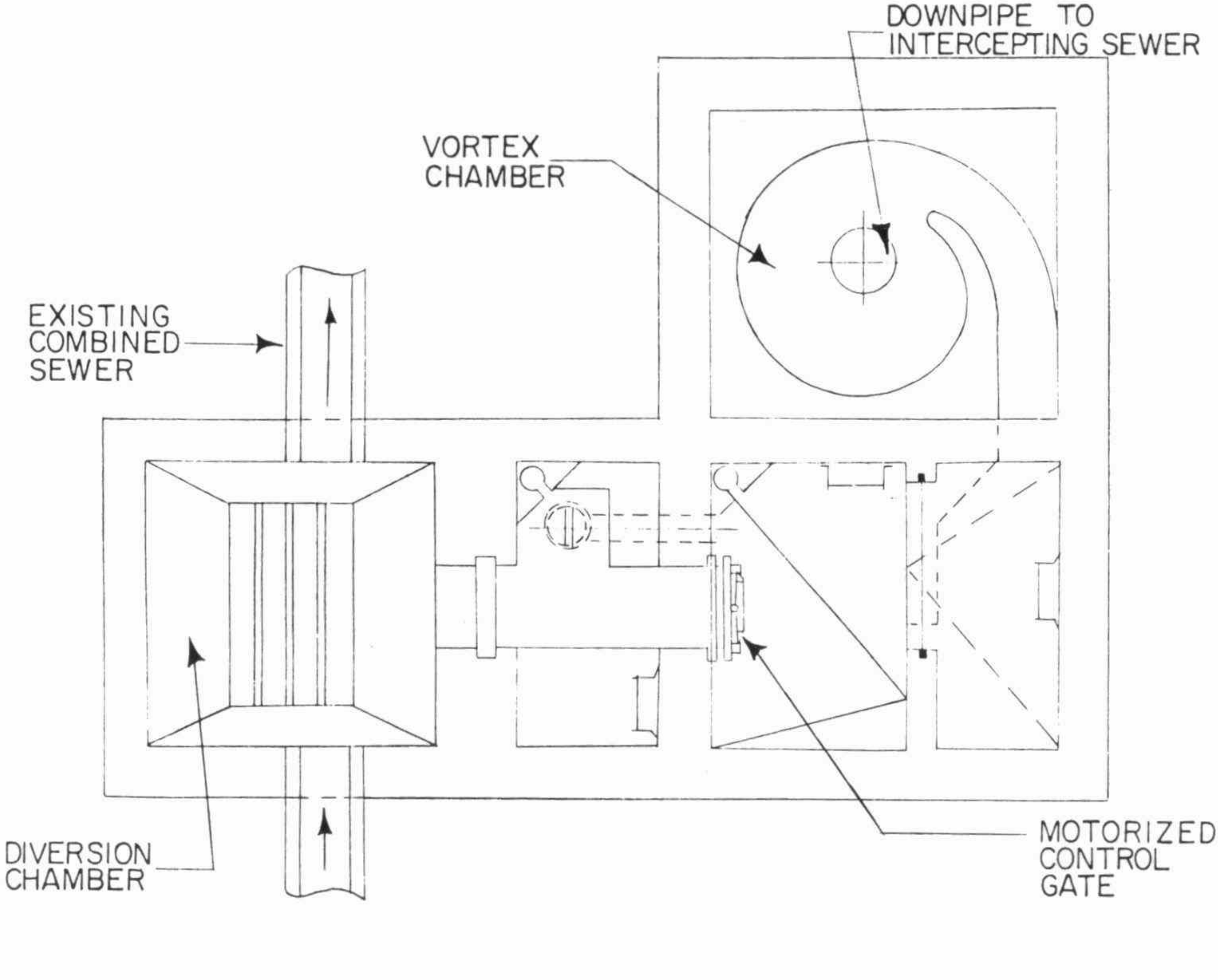


FIGURE 9. TYPICAL ARRANGEMENT OF VORTEX CHAMBER FOR METROPOLITAN TORONTO INTERCEPTING SEWER

With the exception of possibly a few of the larger cities in Canada, such as Halifax and Winnipeg where some interest has been shown, it does not seem that a computer system is an economically feasible consideration.

3.6.2 Drag reducing additives

The possibility of injecting a chemical additive into sewers which have inadequate capacity to handle peak flows, in order to reduce surface friction and increase the flow on a temporary basis, has been demonstrated at an installation in Dallas, Texas. The feasibility of such an injection to improve hydraulic characteristics seemed to have been adequately proven by the system and the additives did not appear to be detrimental to waste treatment plants and receiving waters.

No such installation has been reported in Canada.

3.7 Control by Urban Watershed Management

3.7.1 Street cleaning practices

Street cleaning practices of one form or another are universally used across Canada. There are, however, some variations in the preferred procedures as some municipalities prefer dry sweepers or vacuum sweepers. Other municipalities use street flushing in conjunction with the street sweepers. The frequency of street cleaning is variable and in different municipalities it depends on the type of the area, the roads, weather conditions, availability of funds and the equipment used.

Although personnel at the managerial level generally recognize the dependency of street runoff pollution on their cleaning practices, it seems that this is not likely to extend to the operational staff. Obviously, a better form of communication and dissemination of information is required.

3.7.2 Snow removal

The policies with respect to snow removal are generally recognized to be a municipal responsibility and consequently any policy may vary considerably from one municipality to another.

The scope and extent of the service depends on a number of factors such as snowfall quantities and other local climatic conditions, needs to provide safe driving conditions, especially on the larger traffic arteries, funds available, type and size of organization responsible for snow removal, available disposal facilities, etc.

The variety and sophistication of snow removal equipment is greatly dependent on size of organization, available funds and quantities of snow to be handled. The type of equipment used varies considerably. The most common type of equipment used is plow blades installed on the fronts of trucks to push the snow to one side. Other types are graders, blowers, loaders, trucks and snow melters. Most equipment in use would be adapted from earth moving equipment to afford year-round use. The use of specialized equipment for snow removal only, such as the large snow blowers used on main traffic arteries, and snow melters, such as recently purchased by Metro Toronto, would be primarily subject to cost-benefit consideration.

The frequency of removal is a compromise between available funds and judgements as to what extent snow should be removed to minimize traffic hazards. This may vary from municipality to municipality, with higher sophistication usually prevailing in the larger municipalities, particularly on main traffic arteries.

Winnipeg, Manitoba, reported that regional streets are cleared after one inch of snowfall and sweeping/collection frequency can be three to six times per day.

In general, snow is pushed off the roads and streets wherever practical and possible. In springtime, the melt from such accumulation will run off the same way as rainfall, i.e., into sewers, ditches, water courses, etc. Only where the accumulation becomes too high to keep thoroughfares and property entrances passable is snow loaded and trucked away to designated disposal sites.

A rough assessment, based on snow removal records from one of Metro Toronto's Boroughs, indicates that in the order of three to four percent only of the winter snow accumulation in street, parking

lots and driveways is actually trucked away to special disposal locations. This would mainly come from arterial roadways where traffic hazards are likely to be greatest. This particular removal practice prevails in the densely urbanized areas of the larger cities, where insufficient room is available to push the snow aside for the winter.

Policies, if any, concerning disposal appear to be very general in nature. Most snow dumping may be in areas where the snow melt can readily runoff into open water. Manitoba mentions that no snow disposal in the area of storm water impoundments is permitted. In municipalities along the seacoast of the Maritime provinces, disposal of the snow is usually made by dumping into a harbour. If the snow is melted, such as in Metro Toronto, it is discharged into storm sewers. Most trucked snow would, however, be dumped in lakes and rivers, if ice conditions permit, or on open lots along shorelines.

The Provinces of Quebec and Ontario have shown some concern for the effects of disposal of snow in water courses and other receiving waters, and on waste treatment plant operation. Such concerns most generally prevail in the municipalities located on fresh water rivers and lakes, and most particularly with respect to the Great Lakes - St. Lawrence River System.

Quebec has issued a policy statement regarding the unsightliness of snow dumps along rivers and lakeshores and recommends more careful site selection. The statement also observes that little or no data is available or whether or not snow melt causes appreciable pollution of open water. A few years ago this became an issue in Ontario, when sampling showed appreciable concentrations of salt in receiving waters near melting snow dumps. It is to be realized, however, that wherever snow dumps are located, the melted snow and salt will find its way to open water, in any event, by whatever means of conveyance.

The provinces do not appear to consider snow melt to be critical in sizing sewer pipes. Peak flow from rainfall is considered to be the governing factor instead.

To provide automative traction on city streets during winter snowfalls, most municipalities use a de-icing material such as salt and/or an abrasive material such as sand. This seems to be fairly general in all provinces. The environmental impact of these de-icing and abrasive materials has been given some consideration and some tests have been done in Ontario and in Saskatchewan.

Salt, as a dissolved solid, would not generally be removed in convential sewage treatment to any appreciable extent. Therefore, the only practical way to reduce pollution from winter salt application is to reduce its application to the practical minimum. From the more detailed information provided by Ontario, Manitoba and Saskatchewan, it appears that salt may be generally applied at a rate of 1/4 ton per lane-mile.

The extent of the problems of lead and other heavy metals as snow contaminants is not widely known, although it is realized that there is other general debris mixed with the snow removed from the streets which may be of greater concern than salt. Snow dumps in commercial and industrial areas in Quebec and in some other locations are located so that the melting snow is directed into the sewer system.

The use of sand generally occurs only in special circumstances although it is predominantly used in Quebec City. It provides better traction on icy streets in very cold weather where salt may not be effective in melting the ice. However, sand creates considerable maintenance problems because of its accumulation in gutters, catch basins, in the sewers and at the treatment plant.

3.7.3 Sewer cleaning

In general, it may be observed that the cleaning of combined sewers may not be so crucial as that of sanitary sewers, simply because they are relatively much larger in size. Some cleaning of combined sewers is carried out apart from regular maintenance, particularly if there appears to be some form of obstruction in the sewer.

Various forms of cleaning are utilized, such as bucket operation pulled from one manhole to another, hydraulic spray and, in some instances, balls floated down the sewer in conjunction with sewer flushing.

Because of sewer size, combined sewer flushing during dry weather is only practical for the small pipe sizes, as in the larger pipes no significant scouring of sediments would be achieved.

Catch basins are installed on new combined sewers, if any are constructed. Such catch basins would need to be provided with gulley traps to prevent odours from sanitary flow escaping from the basins. Catch basins are usually cleaned by vacuum gulley cleaner trucks once or twice a year.

3.8 Control by Storm Water Treatment

3.8.1 Attitudes

This is a subject which is being given more and more attention by regulatory bodies. Needless to say, it has not been received with a great deal of enthusiasm by municipal authorities who look at the considerable potential costs involved and have considerable reservations with respect to the benefits to be obtained for these costs. Nevertheless, the Province of Ontario has taken steps in this direction for flows into the Rideau River in the Ottawa area. Manitoba and Quebec are studying the matter and the Province of British Columbia has indicated this to be one of the provincial control objectives and has some studies in progress.

The main objective for treatment at the present time would seem to be the removal of suspended solids, with reduction of biochemical oxygen demand and possible consideration of chlorination for bacteriological contaminants in the outflow. This aspect is being studied in Ontario through the Urban Drainage Subcommittee of the Canada-Ontario Agreement on Great Lakes Water Quality.

3.8.2 Types of treatment

Surface ponds, of course, provide a degree of storm water treatment although it is expected that their prime function is peak flow attenuation.

Storm water tanks also provide storage for reduction of peak flows but their usefulness in quality control is their prime attribute. Because they usually occur as downstream storage they are suitably located for storm water treatment prior to discharge to the receiving water.

Further development of storm water runoff treatment is anticipated in a number of larger municipalities. Certain research work is being undertaken under the auspices of the Urban Drainage Subcommittee (UDS) established under the Canada-Ontario Agreement on Great lakes Water Quality.

3.8.3 Downstream storage practices

3.8.3.1 Surface ponds. Surface ponds are being utilized in Manitoba, principally in the City of Winnipeg, for storm water impoundment. Because of the relatively flat gradients of the land in the area, Winnipeg has found these impoundments to be very advantageous in the control of runoff quantity. A report on storm water management by the use of impoundments, prepared by the City of Winnipeg, Works and Operations Department [5], outlined a number of factors for consideration for the use of impoundments and some of these have been noted previously under Section 2.4. The report was approved and the concept of impoundments was adopted for use in the City.

A small number of surface ponds have been used in Alberta, essentially for much the same purposes as the impoundments used in Winnipeg. In both Alberta and Manitoba, however, it has been found that there is some quality control benefit obtained from the detention ponds due to the settling effects for solids in the flow, particularly the sediment which may be caused by erosion and carried from newly developing areas.

3.8.3.2 Holding tanks. Mostly storm water holding tanks have been used on combined sewer flows. Their purpose is to catch the first flush of solids washed down the combined sewer at the beginning of the storm.

Sometimes these tanks are designed for in-system flows whereby the storm water passes into the tank and flows out the other

end after a predetermined detention time. This time is usually set to provide for a certain proportion of the suspended material to settle to the bottom.

Another type of holding tank is the off-system design whereby the first flush of storm water is diverted into the holding tank until the tank is filled and then the balance of flows in the sewer by-pass the tank and continue down the sewer to the outlet.

It has been found that the pollution aspect of storm water runoff is related to frequent, low intensity storms and to the first flush of solids. The effects of build-up of pollutants on the ground surface over a dry period is also a significant factor. Holding tanks, therefore, tend to catch the first flush from the sewers and, for many storms during the year, will retain the whole volume of runoff. The runoff from the more severe storms, after the initial flush, is much less polluting, due to dilution and the previous flushing action. The effect on the quality of the receiving water is much reduced. For both in-system and off-system storage, when flows in the sewers have returned to normal, the contents of the tank are usually drained back to the sanitary sewer system at a regulated rate.

The Hyde Avenue storm holding tank in the Borough of York, in Metropolitan Toronto, is an example of the in-line system tank. A diagram of flows through the tank is shown in Figure 10 on page 46. This tank was installed a few years ago in order to mitigate the pollution of the Humber River and its tributary, Black Creek, caused by combined sewer discharges.

Quite a few years ago, the City of Toronto installed a storm water holding tank in High Park. This tank was a multi-compartment type of the off-system design. It was located to catch the storm water flows from a number of combined sewers meeting at that location. With the construction, by the Municipality of Metropolitan Toronto, of the new intercepting sewer from Ashbridges Bay to the High Park tank, the existing combined sewers will be intercepted by the new construction and it is understood that the High Park tank will be taken out of service.

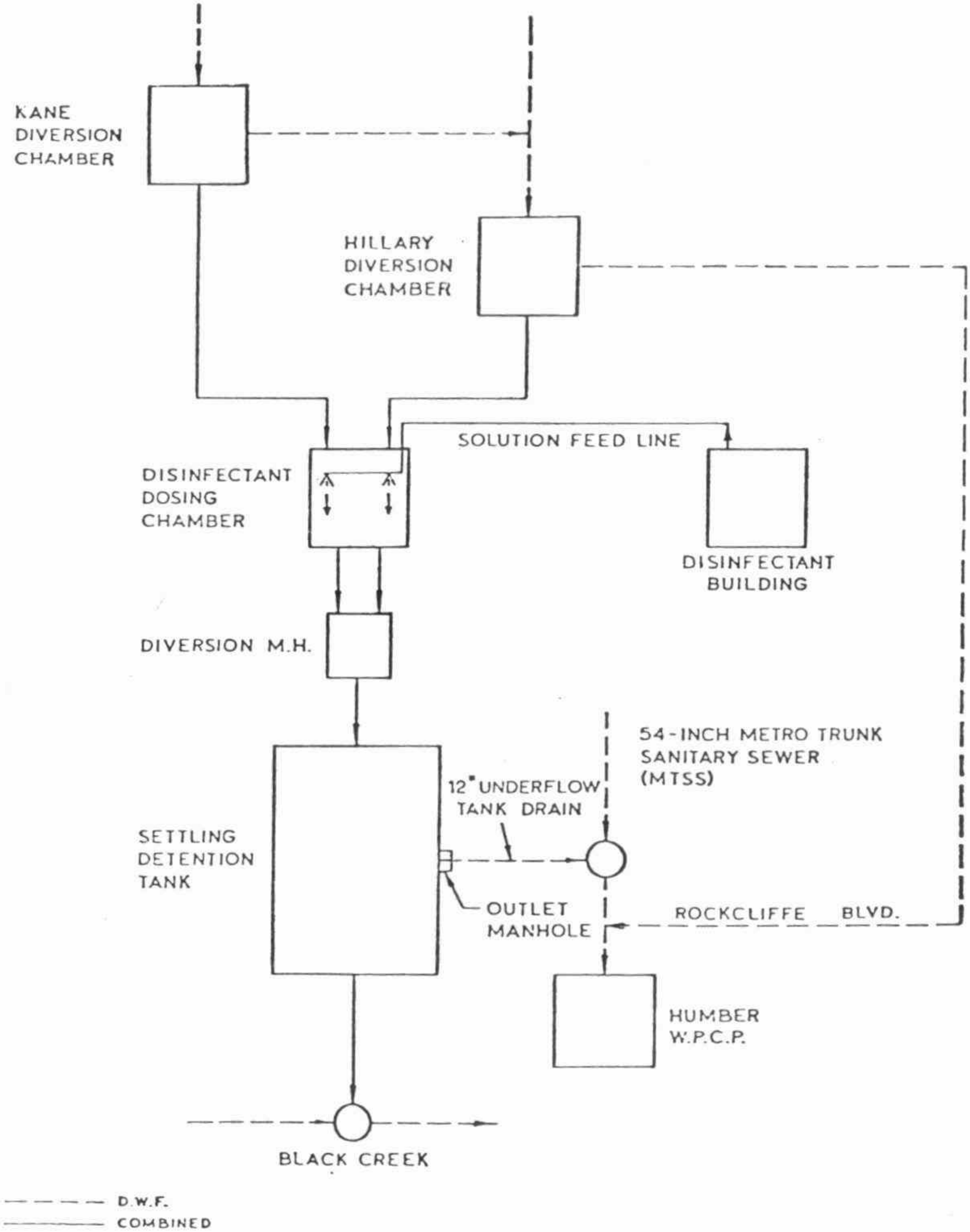


FIGURE 10. FLOW DIAGRAM FOR THE BOROUGH OF YORK, HYDE AVENUE SETTLING DETENTION TANK

A few storm water holding tanks have been installed in Nova Scotia to resolve certain specific problems, on the recommendation of the consulting engineers.

3.8.4 Operational problems

There are a number of safety considerations in the design of surface impoundments, such as depth of water and slopes of banks. In addition, there are some operational problems which require a certain amount of maintenance from time to time. It has been found that nutrients washed from ground surfaces can cause the development of algae in the ponds. The development of mosquito and other insect larvae must also be controlled. Surface ponds are also subject to settling of sediment transported with the storm water and after a period of time this must be removed in order to restore the capacity of the impoundment.

The contents of the storm water holding tanks, which remain after the flow of storm water into the tank has ceased, are usually drained or pumped into the sanitary sewer system. This practice takes up some capacity in the sanitary sewers, but if the discharge is properly timed and regulated this should not create any problem. Whether the tank contents are discharged to the sanitary system or returned to the storm system will be somewhat dependent on the assimilative capacity of the receiving water and the degree of treatment required.

There are some feelings that the settled solids should not be returned to the sewer. There are advantages and disadvantages to be considered. By returning these solids to the sanitary sewer they will be treated at the water pollution control plant, but there is concern that some of these solids will settle in the sewer pipe during periods of low sanitary flow. A considerable increase in maintenance and operational problems would occur if this material was to be removed from the tanks and disposed in a suitable location. This could be a considerable factor if a number of holding facilities are required throughout a municipality and the contents of each tank were to be removed for disposal.

4. FIELD STUDIES

4.1 Purpose of Field Studies

With some exceptions, most municipalities grow through the years. New development requires design of new sewers, and where sewer services of new subdivisions drain into existing systems, an analysis of the relevant part of the existing system becomes necessary. Redevelopment to higher densities in existing areas similarly may require review of the capabilities and condition of existing systems. From practical experience, very few municipalities have a complete and thorough documentation of all facets of their sewer systems, including complete data on actual locations, actual lengths, grades, age and condition of pipe materials, flow velocities, capacities, rate of utilization, conditions of joints, connections, modifications, manholes, etc.

Field studies provide a background data basis that can be used to formulate projections for future requirements. This information may be required to adequately design new sewer systems based on current conditions. It may also be highly desirable to investigate any abnormal conditions which may be occurring in the sewer, such as excess infiltration or inflow, so that they can be rectified.

Mathematical simulation models will provide the means for quick and extensive evaluation of alternative solutions, when circumstances such as new development require enlargement or upgrading of existing systems. They eliminate tedious and often incomplete manual analysis and re-assessment of the existing systems relative to new needs.

Some of the new mathematical simulation models are quite sophisticated in the detail which is incorporated in the program. Since, in any computer program, the results which come out are only as reliable as the information which went in, it becomes necessary to collect actual field data for input into the program so that the model can be calibrated for the actual location and condition that it is being asked to analyze. Along the same lines, sufficient field data must be collected to enable determination of the different hydro-

logical parameters of the area and to provide a reasonable reference against which the results from computer simulation can be verified.

Both the study needs and the available funds often dictate whether additional field work is required. Seldom, if ever, is there an abundance of records. The decision whether gaps need to be filled is often made on a practical basis weighing costs against needs.

4.2 Measurements and Methods

4.2.1 Measurements

The main concerns for field study measurements are those features that indicate runoff quantity and runoff quality. It is necessary, therefore, to observe the physical features of not only the sewers themselves, but of surface parameters from the quantitative and qualitative aspect. This might include such things as ground slopes, depression areas, impervious areas, ground surface characteristics, drainage patterns, flood levels, etc. It is desirable, also, to determine a coefficient for calculating flow in the sewer pipe which can be used in analyzing conditions at varying flow quantities. Other quantities that need to be measured are the precipitation rate, variations in the flow rate indicated by rising or falling water levels, and the quality of the runoff through sampling.

4.2.2 Methods

Wherever possible, it is desirable to have the precipitation quantities measured as near as possible to the centre of the drainage area contributory to the sewer being monitored. The number of precipitation measurement locations will depend, to some degree, on the size of the drainage area being observed and the accuracy required for the calibration of the model. In some locations, the precipitation records of the local weather office may be the only source of information.

One other aspect which is highly important once physical features are obtained is the ability to correlate the precipitation, flow and quality measurements. For this purpose, it is necessary that continuous recording instruments be used as much as possible for these measurements so that the timing of instantaneous variations can

be coordinated amongst the various measurements. Centralized recording on a common chart recorder provides optimum time matching of all input parameters. Microprocessor or computer controlled data collection systems are gaining increasing acceptance for larger projects, especially where the volume of data to be collected and processed becomes prohibitive for manual analysis.

4.2.3 Instrumentation

There are many types of instruments for measuring the various features. For measuring rainfall rates, the tipping bucket rain gauge is usually the most economic instrument, providing easy interfacing with recording instruments and telemetry systems.

For the measurement of the flow rate, a huge variety of different instruments is available on the market, many of them making extensive use of the latest techniques in digital electronics. Built-in processors convert measured depth and velocity signals into flow and control associated equipment such as samplers. The depth sensors used range from conventional floats, bubblers and "dippers" to ultra-sonic sensors and magnetic pickups. The applicability of each instrument for a given situation depends very much on the local circumstances. Of particular importance are the hydraulic conditions of the conduit in which the flow is to be measured and the method of measurement, whether by depth or by use of a measuring device such as a weir, flume or orifice.

One must be fully conscious of practical limitations to ideal conditions of measurement that do not adequately provide for backwater conditions or bottom sediment, etc. which may influence the results by several orders of magnitude. Surcharge conditions may require differential level measurements between adjacent manholes in order to obtain acceptable flow data.

There are a number of devices for sampling water quality. These generally consist of a small vacuum pump with a suction tube into the water flow at a suitable location. The liquid is usually drawn into a metering chamber from which it is released into a large common container or into a series of individual bottles. Sampling can be taken on a flow-proportional basis or sequentially, controlled by

a preset timer. Most available samplers have some kind of purging feature which cleans the sampling line between each sample. A few units provide also an event signal that allows the recording of the exact time a sample was taken. This is essential for short-interval sampling of storm runoff, to properly correlate measured hydrographs and pollutographs. The synchronization of all events on a time scale is most important.

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